EG&G

Model 7310

Noise-Rejecting Voltmeter

Instruction Manual

190250-A-MNL-A

MP MASTER

MA29031

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Noise-Rejecting Voltmeter

Instruction Manual

190250-A-MNL-A

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This equipment generates, uses, and can radiate radio-frequency energy and, if not installed and used in accordance with this manual, may cause interference to radio communications. As temporarily permitted by regulation, operation of this equipment in a residential area is likely to cause interference, in which case the user at his own facility will be required to take whatever measures may be required to correct the interference.

Declaration of Conformity

This product conforms to EC Directives 89/336/EEC Electromagnetic Compatibility Directive, amended by 92/31/EEC and 93/68/EEC, and Low Voltage Directive 73/23/EEC amended by 93/68/EEC.

This product has been designed in conformance with the following IEC/EN standards:

EMC: BS EN55011 (1991) Group 1, Class A (CSPIR 11:1990)
BS EN50082-1 (1992):
IEC 801-2:1991
IEC 801-3:1994
IEC 801-4:1988

Safety: BS EN61010-1: 1993 (IEC 1010-1:1990+A1:1992)

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WARRANTY ..... End of Manual

Introduction

Chapter 1

1.1 How to Use This Manual

This manual gives detailed instructions for setting up and operating the EG&G Model 7310 Noise-Rejecting Voltmeter. It is split into the following chapters:-

Chapter 1 - Introduction
Provides an introduction to the manual, briefly describes the function of a noise-rejecting voltmeter, the types of measurement for which it may be used and what it actually measures, and lists the major specifications of the model 7310.

Chapter 2 - Installation and Initial Checks
Describes how to install the instrument and gives a simple test procedure that may be used to check that the unit has arrived in full working order.

Chapter 3 - Technical Description
Provides an outline description of the design of the instrument and discusses the effect of the various controls. A good understanding of the design will enable the user to get the best possible performance from the unit. The chapter also includes information on good measurement techniques.

Chapter 4 - Front and Rear Panels
Describes the connectors, controls and indicators which are found on the unit and which are referred to in the subsequent chapters.

Chapter 5 - Front Panel Operation
Describes the capabilities of the instrument when used as a manually operated unit, and indicates how to operate it using the front panel controls.

Chapter 6 - Computer Operation
This chapter provides detailed information on operating the instrument from a computer over either the GPIB (IEEE-488) or RS232 interfaces. It includes information on how to establish communications, the functions available, the command syntax and a detailed command listing.

Appendix A
Gives the detailed specifications of the unit.

Appendix B
Details the pinouts of the multi-way connectors on the rear panel.

Appendix C
Lists three simple terminal programs that may be used as the basis for more complex user-written programs.

Appendix D
Shows the connection diagrams for suitable RS232 null-modem cables to connect the unit to an IBM-PC or 100 % compatible computer.

Appendix E
Gives an alphabetical listing of the computer commands for easy reference.

Appendix F
Provides a listing of the instrument settings produced by using the Auto-Default function.

New users are recommended to unpack the instrument and carry out the procedure in chapter 2 to check that it is working satisfactorily. They should then make themselves familiar with the information in chapters 3, 4 and 5, even if it is intended that the unit will eventually be used under computer control. Only when they are fully conversant with operation from the front panel should they then turn to chapter 6 for information on how to use the instrument remotely. Once the structure of the computer commands is familiar, appendix E will prove convenient as it provides a complete alphabetical listing of these commands in a single easy-to-use section.

1.2 What is a Noise-Rejecting Voltmeter?

Many procedures involve the measurement of AC voltages and currents. If the signal levels are large then they usually dominate any accompanying electrical noise, allowing conventional instruments, such as digital voltmeters (DVM) and oscilloscopes to be used. Conversely, if the signals of interest are very weak and contaminated with large levels of electrical noise then specialized techniques employing coherent detectors, such as lock-in amplifiers, may have to be used. Although these latter methods produce excellent results, they require the measurement instrument to be supplied with a reference signal, which is phase-locked to the signal of interest, and this is not always available.

Between these extremes there are a large number of applications where the signal is accompanied by noise, which makes accurate and repeatable measurements difficult to achieve. Examples include the measurement of strain gauge outputs, detecting one frequency component in a circuit where several frequencies are present, AC bridge null detection and the removal of line frequency pick-up. It is in these and similar areas that the EG&G model 7310 Noise-Rejecting Voltmeter will be of most use.

The instrument is, in effect, a precision, true r.m.s. voltmeter together with a signal filtering and conditioning stage all in one box. Signals to be measured, which may be either voltages or currents, are passed through the filter stage thereby restricting the signal bandwidth reaching the voltmeter. The filter may be operated in either bandpass or low-pass mode and adjusted in terms of center frequency and Q-factor (bandwidth) or upper frequency roll-off respectively. This allows the user to select the most appropriate settings to match the frequency components of the signal of interest. The voltmeter then measures the r.m.s. level of the filtered signal and displays it on the front panel. Minimum and maximum signal level indicators and a bar-graph

display facilitate the monitoring of signal level changes. In addition, many extra capabilities, such as auxiliary analog and digital inputs and outputs, data storage and full computer control interfaces, are included thereby avoiding the need, in many instances, to use any other instruments.

The model 7310 uses a combination of precision, low-noise analog electronics and the latest developments in Digital Signal Processing (DSP), to provide an instrument of outstanding stability and accuracy. It is supplied with a full calibration certificate, traceable to international standards, and will therefore find use both for industrial on-line quality control measurements as well as in research and development.

The model 7310 Noise-Rejecting Voltmeter can function as a:-

- True r.m.s. voltage or current meter
- Tuned Filter
- Peak Level Detector
- Ratiometer
- Transient Recorder
- Spectrum Analyzer

These characteristics, all available in a single compact unit, make it an invaluable addition to the range of measuring instruments in any facility.

1.3 What Does it Measure?

The model 7310 may be operated in either DC or AC measurement modes. In the former mode, it acts as a DC voltmeter with output averaging or smoothing, indicating the mean level of a DC input signal over a period of time, set by the output averaging controls. This mode is commonly used for monitoring slowly-changing DC signals.

The AC measurement mode measures the AC root-mean-square (r.m.s.) value of the input signal after any filtering. In physical terms, the r.m.s. value of an AC waveform is the equivalent DC value that would generate the same amount of heat in a resistor. True r.m.s. measurement greatly simplifies the analysis of complex signals. Since the r.m.s. value is the DC equivalent of the original waveform, it provides a reliable basis on which to compare dissimilar waveforms.

Many traditional AC-indicating techniques, such as a rectifier followed by an analog meter, give an average output rather than a true r.m.s. value. Although their scaling is usually adjusted so that they indicate the r.m.s. value for noise-free sinusoidal inputs, they do not display the correct r.m.s. readings for other signal types. In some cases the error can exceed 10 %, making accurate comparisons impossible.

The model 7310 calculates the r.m.s. value using a digital algorithm and hence its outputs are correct, not only for noise-free sinusoidal inputs, but also for mixed frequencies, modulated signals, squarewaves, sawtooth waveforms, random noise, rectangular pulses with a low duty cycle, etc.. Naturally, accurate measurements can only be achieved if all frequency components of the waveform being measured lie within the instrument's bandwidth.

1.4 Key Specifications and Benefits

The EG&G model 7310 Noise-Rejecting Voltmeter offers:-

- Frequency range: DC and 0.3 Hz to 60 kHz
- Voltage sensitivity: AC: 10 μV to 1 V full-scale
  DC: 1 mV to 1 V full-scale
- Current input mode sensitivity: AC: 10 pA to 1 μA full-scale
  DC: 1 nA to 1 μA full-scale
- Line frequency rejection filter can be set to reject signals at F, 2F, F and 2F or may be turned off
- Programmable signal channel digital filter with adjustable selectivity (*Q*-factor) and hence bandwidth
- Input signal spectral analysis using Fast Fourier Transform (FFT) and display to help in setting filter controls
- Analog output of signal after digital filtering
- True r.m.s. measuring stage with 5-digit output display
- Analog voltage output proportional to digital display
- Minimum and Maximum Level indicators
- Ratio mode with output expressed in decibels with respect to reference level
- Display smoothing control
- 8-bit programmable digital output port for external system control
- Two auxiliary Analog-to-Digital Converter (ADC) inputs
- Four auxiliary Digital-to-Analog Converter (DAC) outputs
- Full range of auto-modes
- Standard GPIB (IEEE-488) and RS232 interfaces with RS232 daisy-chain capability to allow up to 16 instruments to be controlled from a single computer port
- Large back-lit liquid crystal display (LCD) with menus for control and display of instrument outputs in both digital and graphical formats
- 32768 point internal curve storage buffer

Installation & Initial Checks

Chapter 2

2.1 Installation

2.1.01 Introduction

Installation of the model 7310 in the laboratory or on the production line is very simple. Because of its low power consumption, the model 7310 does not incorporate forced-air ventilation. It can be operated on almost any laboratory bench or be rack-mounted, using the optional accessory kit, at the user's convenience. With an ambient operating temperature range of 0 °C to 35 °C, it is highly tolerant to environmental variables, needing only to be protected from exposure to corrosive agents and liquids.

2.1.02 Rack Mounting

An optional accessory kit, part number K02003, is available from EG&G Instruments to allow the model 7310 to be mounted in a standard 19-inch rack.

2.1.03 Inspection

Upon receipt the model 7310 Noise-Rejecting Voltmeter should be inspected for shipping damage. If any is noted, EG&G INSTRUMENTS should be notified immediately and a claim filed with the carrier. The shipping container should be saved for inspection by the carrier.

2.1.04 Line Cord Plug

A standard IEC 320 socket is mounted on the rear panel of the instrument and a suitable line cord is supplied.

2.1.05 Line Voltage Selection and Line Fuses

Before plugging in the line cord, ensure that the model 7310 is set to the voltage of the AC power supply to be used.

A detailed discussion of how to check and, if necessary, change the line voltage setting follows.

CAUTION: The model 7310 may be damaged if the line voltage is set for 110 V AC operation and it is turned on with 220 V AC applied to the power input connector.

The model 7310 can operate from any one of four different line voltage ranges, 90-110 V, 110-130 V, 200-240 V, and 220-260 V, at 50-60 Hz. The change from one range to another is made by repositioning a plug-in barrel selector internal to the Line Input Assembly on the rear panel of the unit. Instruments are normally shipped from

the factory with the line voltage selector set to 110-130 V AC, unless they are destined for an area known to use a line voltage in the 220-260 V range, in which case, they are shipped configured for operation from the higher range.

The line voltage setting can be seen through a small rectangular window in the line input assembly on the rear panel of the instrument (figure 2-1). If the number showing is incorrect for the prevailing line voltage (refer to table 2-1), the barrel selector will need to be repositioned as follows.

Observing the instrument from the rear, note the plastic door immediately adjacent to the line cord connector (figure 2-1) on the left-hand side of the instrument. When the line cord is removed from the rear panel connector, the plastic door can be opened outwards by placing a small, flat-bladed screwdriver in the slot on the right-hand side and levering gently. This gives access to the fuse and to the voltage barrel selector, which is located at the right-hand edge of the fuse compartment. Remove the barrel selector with the aid of a small screwdriver or similar tool. With the barrel selector removed, four numbers become visible on it: 100, 120, 220, and 240, only one of which is visible when the door is closed. Table 2-1 indicates the actual line voltage range represented by each number. Position the barrel selector such that the required number (see table 2-1) will be visible when the barrel selector is inserted and the door closed.

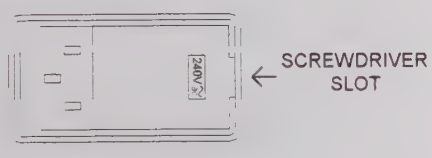


Figure 2-1, Line Input Assembly

VISIBLE #	VOLTAGE RANGE
100	90 - 110 V
120	110 - 130 V
220	200 - 240 V
240	220 - 260 V

Table 2-1, Range vs Barrel Position

Next check the fuse rating. For operation from a nominal line voltage of 100 V or 120 V, use a 20 mm slow-blow fuse rated at 1.0 A, 250 V. For operation from a nominal line voltage of 220 V or 240 V, use a 20 mm slow-blow fuse rated at 0.5 A, 250 V.

To change the fuse, first remove the fuse holder by pulling the plastic tab marked with an arrow. Remove the fuse and replace with a slow-blow fuse of the correct voltage and current rating. Install the fuse holder by sliding it into place, making sure the arrow on the plastic tab is pointing downwards. When the proper fuse has been installed, close the plastic door firmly. The correct selected voltage setting should now

be showing through the rectangular window. Ensure that only fuses with the required current and voltage ratings and of the specified type are used for replacement. The use of makeshift fuses and the short-circuiting of fuse holders is prohibited and potentially dangerous.

NOTE: After changing the line voltage setting, be sure to check, and if necessary change, the line-frequency rejection filter frequency setting to match the prevailing line frequency - see procedure given in section 2.3.

2.1.06 Accessories

The model 7310 is supplied with a ×1 oscilloscope-type probe equipped with various accessories. This probe may be used for single-ended voltage or current measurements, and, since it is of unity-gain, no correction needs to be applied to the 7310's displays.

Alternatively, of course, the input signal(s) may be directly connected to the input BNC connector(s) using suitable user-supplied cables.

2.2 Initial Checks

2.2.01 Introduction

The following procedure checks the performance of the model 7310. In general, this procedure should be carried out after inspecting the instrument for obvious shipping damage.

NOTE: Any damage must be reported to the carrier and to EG&G INSTRUMENTS immediately. Additionally the shipping container must be retained for inspection by the carrier.

Note that this procedure is intended to demonstrate that the instrument has arrived in good working order, not that it meets specifications. Each instrument receives a careful and thorough checkout before leaving the factory, and, if no shipping damage has occurred, will perform within the limits of the quoted specifications. If any problems are encountered in carrying out these checks, contact EG&G INSTRUMENTS or the nearest authorized representative for assistance.

2.2.02 Procedure

1) Ensure that the model 7310 is set to the line voltage of the power source to be used, as described in section 2.1.05.

2) With the instrument's power switch (located on the rear panel at the extreme top left-hand corner of the instrument when viewed from the rear) set to **0** (off), plug in the line cord to an appropriate line source.

3) Turn the power switch to the **I** (on) position.

4) The instrument's front panel display will now briefly display the following:-

Figure 2-2, Opening Display

5) Wait until the opening display has changed to the Main Display and then press the **MENU** key on the front panel once to enter the Main Menu, shown below in figure 2-3.

Figure 2-3, Main Menu

6) Press one of the keys adjacent to the Auto Functions menu item to enter the Auto Functions menu, shown below in figure 2-4.

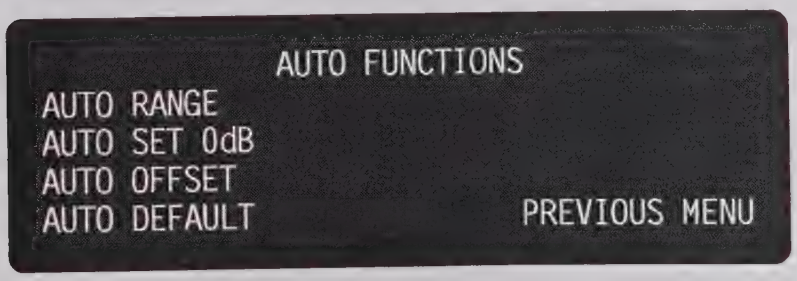


Figure 2-4, Auto Functions Menu

7) Press one of the keys adjacent to the Auto Default menu item. This will set all of the instrument's controls and the display to a defined state. The display will revert to the Main Display, similar to that shown below in figure 2-5, with the right-hand side showing the measured signal present at the **A** input connector in volts rms, both as a digital indication and on a bar-graph. The full-scale sensitivity range is set to 500 mV, and the Maximum and Minimum indicators are reset. The

left-hand side shows that the main digital filter is operating in the bandpass mode with a center frequency of 1000 Hz and a *Q*-factor of 2, giving a -3 dB bandwidth of 322 Hz.

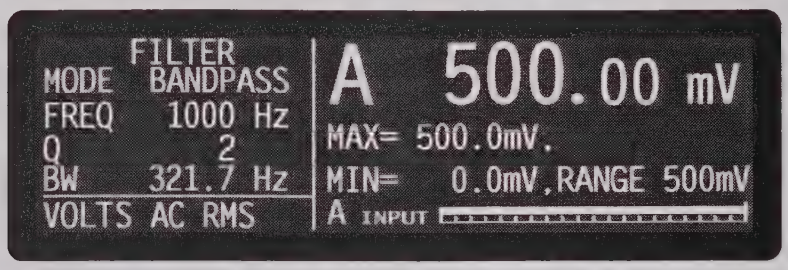


Figure 2-5, Main Display

8) A test signal is now required, for which you will need to provide an external signal generator. This should be set to give a sinusoidal output of 1000 Hz and 1.414 V peak-to-peak (500.0 mV rms) and should provide a source impedance of < 1000 Ω. If the generator is calibrated then you may rely on its calibration, but if not then you will need to use an oscilloscope to monitor its frequency and amplitude.

9) Connect the test signal to the **A** input connector on the front panel of the model 7310 using a suitable cable.

10) The right-hand side of the display should now indicate A, the input signal, close to 500 mV rms.

11) Disconnect the cable from the **A** input connector and confirm that the display returns to zero. Press the **RESET** key on the front panel and check that the maximum and minimum indicators are both reset to zero.

12) Reconnect the test signal to the **A** input connector and change the frequency of the signal generator to 500 Hz. The displayed value should fall to close to 50 mV.

This completes the initial checks. Even though the procedure leaves many functions untested, if the indicated results were obtained then the user can be reasonably sure that the unit incurred no hidden damage in shipment and is in good working order.

2.3 Line Frequency Filter Setting

2.3.01 Introduction

The model 7310 incorporates a line frequency rejection filter which is normally supplied set to 60 Hz. If the frequency of the power line to be used is also 60 Hz then the setting does not need to be changed. If, however, the unit is to be used in an area with a 50 Hz power line frequency the setting should be changed using the following procedure.

2.3.02 Procedure

1) Turn the model 7310's power switch to the **I** (on) position.

2) The instrument's front panel display will now briefly display the following:-

Figure 2-6, Opening Display

3) Wait until the opening display has changed to the Main Display and then press the **MENU** key on the front panel once to enter the Main Menu, shown below in figure 2-7.

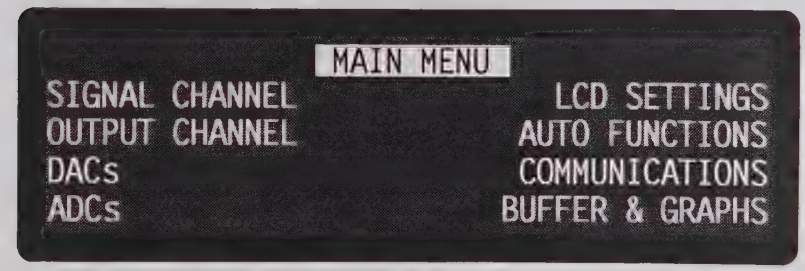


Figure 2-7, Main Menu

4) Press one of the keys adjacent to the Signal Channel menu item to enter the Signal Channel menu, shown below in figure 2-8.

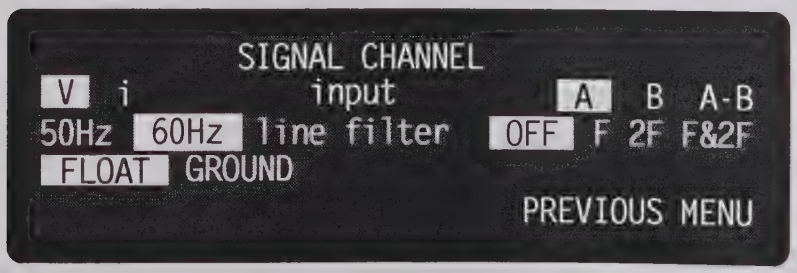


Figure 2-8, Signal Channel Menu - Voltage Input Mode

5) The present line frequency setting is shown in reverse text adjacent to the "line filter" label and is either 50 Hz or 60 Hz. In figure 2-8, the filter is set to 60 Hz. If this setting does not match the prevailing line frequency, then press a key adjacent to this item once to change it.

6) Press the **MENU** key once to return to the Main Display.

This completes the procedure for changing the line frequency setting.

Technical Description

Chapter 3

3.1 Introduction

The model 7310 Noise-Rejecting Voltmeter is a sophisticated instrument with many capabilities beyond those needed for its principal function. This chapter describes the design of the instrument by considering it as a series of functional blocks, with the purpose of each block, and the effect that the controls have on it, being discussed in detail. Although not strictly necessary to operate the instrument, a good understanding of its design will help the user to get the best possible performance from the unit.

3.2 Measurement Modes

The instrument is primarily intended for making frequency-selective voltage and current measurements in the frequency range 1 Hz to 60 kHz. It may also be used to measure the average value, or DC component, of signals, although with a reduced maximum sensitivity.

3.3 Principles of Operation

3.3.01 Block Diagram

The model 7310 utilizes an analog-to-digital converter (ADC), digital signal processor (DSP) and a microprocessor together with very low-noise analog circuitry to achieve its specifications. A block diagram of the instrument is shown in figure 3-1, and the sections that follow describe how each functional block operates and the effect it has on the instrument's performance.

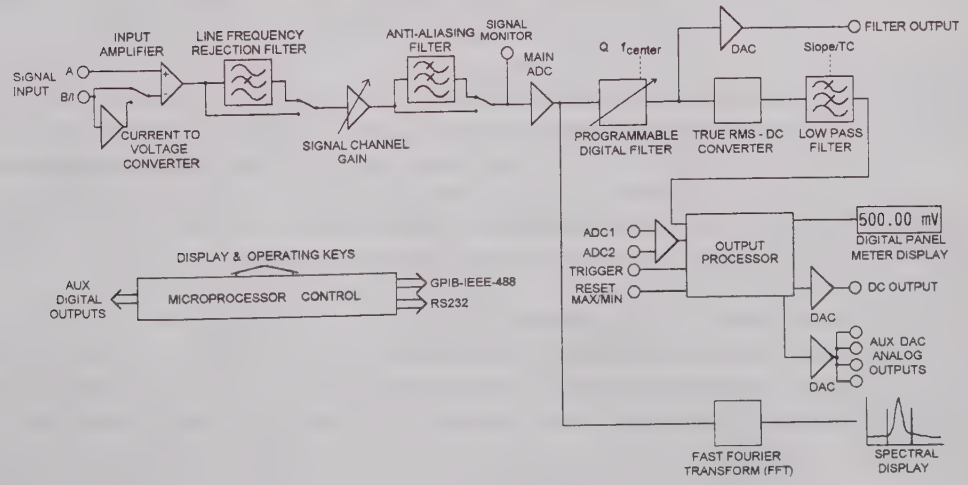


Figure 3-1, Model 7310 - Block Diagram

3.3.02 Signal Inputs

The signal input amplifier can be configured for either single-ended or differential voltage mode operation, or single-ended current mode operation. In either mode the input connector shells may be floated via a 1 kΩ resistor or grounded to the instrument's chassis ground. These features are discussed in the following paragraphs.

Input Connector Selection, A / B / A-B
When set to the A mode, the instrument measures the voltage between the center and the shell of the **A** input BNC connector, whereas when set to the A-B mode it measures the difference in voltage between the center pins of the **A** and **B/I** input BNC connectors.

The latter, differential, mode is often used to eliminate ground loops, although it is worth noting that at very low signal levels it may be possible to make a substantial reduction in unwanted offsets by using this mode, with a short-circuit terminator on the **B/I** connector, rather than by simply using the A input mode.

The specification defined as the Common Mode Rejection Ratio, C.M.R.R., defines how well the instrument rejects common mode signals applied to the **A** and **B/I** inputs when operating in differential input mode. It is usually given in decibels. Hence a specification of > 100 dB at 1 kHz implies that a common mode 1 kHz signal (i.e. a signal simultaneously applied to both **A** and **B/I** inputs) of 1 V r.m.s. will give rise to less than 10 μV r.m.s. of output signal from the input amplifier stage.

The input can also be set to the B mode, in which case the instrument measures the voltage between the center and the shell of the **B/I** input connector. This extra mode effectively allows multiplexing between two different single-ended signals, which are applied to the **A** and **B/I** connectors.

Input Connector Shell, Ground / Float
The input connector shells may be connected either directly to the instrument's chassis ground or they can be floated by being connected via a 1 kΩ resistor. When in the float mode, the presence of this resistor substantially reduces the problems which often occur in low-level signal measurements due to ground loops.

CAUTION: Since the resistance between the shell(s) of the input connector(s) with respect to the instrument's chassis ground is either zero or 1 kΩ, take care when connecting the "grounded" side of the input cable or oscilloscope probe to any grounded circuitry to avoid short-circuits. If measurements have to be made on grounded circuitry and if the maximum common voltage is less than 5 V DC then it is preferable to use the differential input mode.

Input Signal Selection, V / I
Although the voltage mode input is most commonly used, a current-to-voltage converter may be switched into use to provide current mode input capability. In this case the signal is connected to the **B/I** connector. Most high impedance sources (> 100 kΩ) are inherently current sources and need to be measured with a low impedance current mode input. Even when dealing with a voltage source in series

with a high impedance, the use of the current mode input may provide advantages in terms of improved bandwidth and immunity from the effects of cable capacitance.

Although suitable for many measurements, the converter is not recommended for use at frequencies above about 20 kHz. At higher frequencies, better performance can be achieved by using a separate current preamplifier, such as the EG&G model 5182.

Input Coupling
When the instrument is set to the AC measurement mode (see section 3.3.09) the input circuitry is AC-coupled. This has the effect of introducing a high-pass filter response with a -3 dB point at about 300 mHz. A plot of the gain versus frequency response for this circuit is given in figure 3-2.

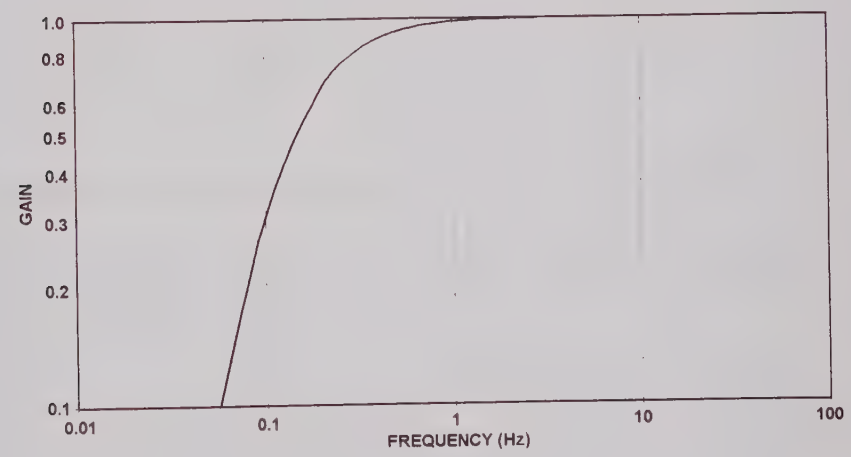


Figure 3-2, AC measurement Mode - Low Frequency Roll-Off

In the DC measurement mode there is no coupling capacitor.

3.3.03 Line Frequency Rejection Filter

Following the input amplifier, the signal may, optionally, be passed through a line frequency rejection filter, which is designed to give greater than 40 dB of attenuation at the power line frequencies of 50 Hz or 60 Hz and their second harmonics at 100 Hz and 120 Hz.

The filter uses two cascaded second-order rejection stages with "notch" characteristics, allowing it to be set to reject signals at frequencies equal to either or both of the fundamental and second harmonic of the line frequency. Hence the filter control settings are "OFF", "F", "2F" or "F & 2F". Gain versus frequency plots for each of the three possible settings when a filter is in use are given in figures 3-3, 3-4 and 3-5. Note that the frequency axes are normalized to the line frequency setting of the instrument, so that, for example, if the frequency is set to 60 Hz and the filter is set to the "F" mode then the gain at 36 Hz (i.e. a normalized frequency of 36/60, or 0.6) will be about 1 dB down.

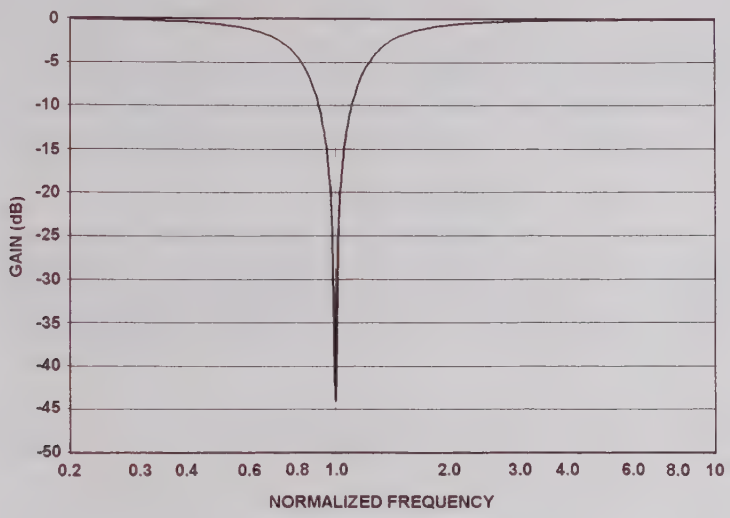


Figure 3-3, Line Frequency Rejection Filter - "F" Setting

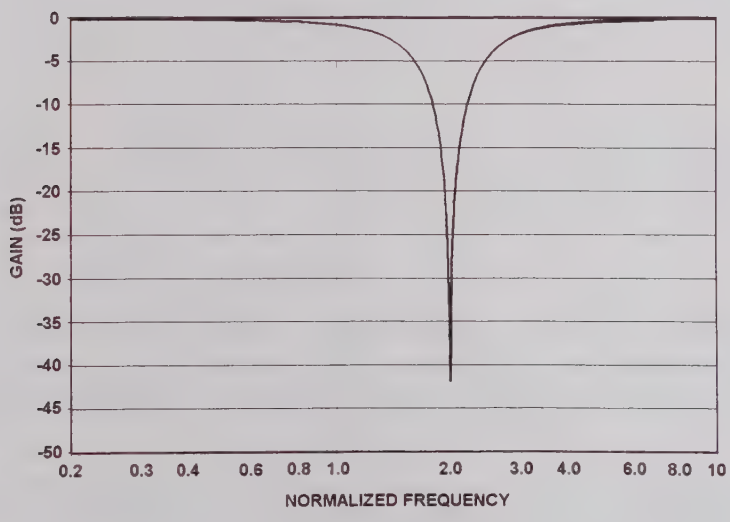


Figure 3-4, Line Frequency Rejection Filter - "2F" Setting

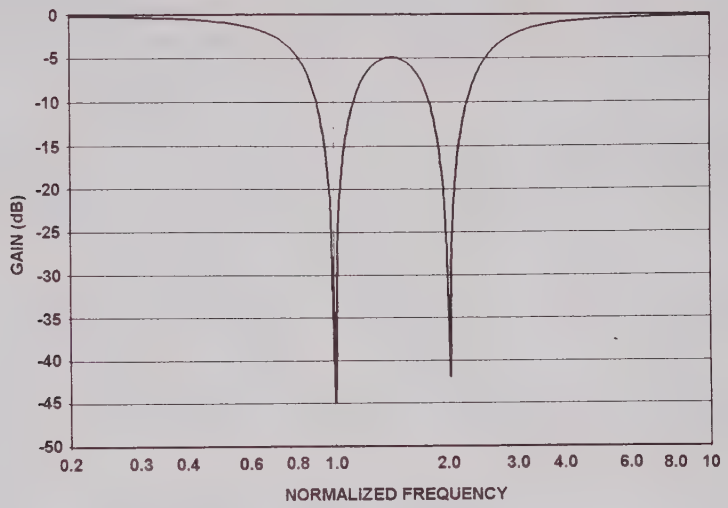


Figure 3-5, Line Frequency Rejection Filter - "F&2F" Setting

It can be seen from these plots that the filters introduce significant attenuation, in the frequency range 10 Hz to 400 Hz, which should be allowed for when measuring signals of frequencies in or close to this range.

The instrument is normally supplied with the line frequency rejection filter center frequency set to 60 Hz. If this is not the same as the line frequency to be used then the filter setting will need to be changed. This can be done manually using the Signal Channel menu by following the procedure discussed earlier in section 2.3, or via a computer command, LF (see section 6.4.01).

3.3.04 Signal Channel Gain

The signal channel contains a number of amplifiers, the overall gain of which is represented on the diagram as the Signal Channel Gain functional block. It is a basic property of any digital signal processing (DSP) instrument that the best performance is obtained by presenting as large a signal as possible to the main analog-to-digital converter (ADC). Therefore, in principle, the Signal Channel Gain value should be made as large as possible without causing the signal channel amplifier or converter to overload. The instrument automatically adjusts the Signal Channel Gain, as the full-scale sensitivity range is changed, to satisfy this criterion.

3.3.05 Anti-Aliasing Filter

When the programmable digital filter measurement mode is set to Bandpass or Low-pass (see section 3.3.07), the signal is passed through an anti-aliasing filter prior to the main ADC. The purpose of this filter is to remove unwanted frequencies which would cause a spurious output from the ADC due to the nature of the sampling process.

Consider the situation when the instrument is measuring a sinusoidal signal of frequency f_{signal} Hz, which is sampled by the main ADC at a sampling frequency $f_{sampling}$ Hz. In order to ensure correct operation of the instrument the output values representing the f_{signal} frequency must be uniquely generated by the signal to be measured, and not by any other process.

However, if the input to the ADC has, in addition, an unwanted sinusoidal signal with frequency f_1 Hz, where f_1 is greater than half the sampling frequency, then this will appear in the ADC output as a sampled-data sinusoid with frequency less than half the sampling frequency, $f_{alias} = |f_1 - nf_{sampling}|$, where n is an integer. This alias signal is indistinguishable from the ADC output generated when a genuine signal at frequency f_{alias} is sampled. If the instrument is being operated in the Bandpass or Low-pass modes, and if the frequency of the unwanted signal were such that the alias signal frequency produced from it was close to, or equal to, that of the wanted signal, then it is clear that the output reading would be in error.

For example, if the sampling frequency were 200 kHz then half the sampling frequency would be 100 kHz. Let the instrument be operating in Bandpass mode and be measuring a signal of 40 kHz accompanied by an interfering signal of 150 kHz. The output of the ADC would therefore include a sampled-data sinusoid of 40 kHz (the required signal) and, applying the above formula, an alias signal of 50 kHz (i.e. |150 kHz - 200 kHz|). If the required signal frequency were now increased towards 50 kHz, and the Bandpass filter retuned to the same frequency, then the output of the instrument would increasingly be affected by the presence of the alias signal and the accuracy of the measurement would deteriorate.

To overcome this problem the signal is fed through the anti-aliasing filter which restricts the signal bandwidth to the maximum operating frequency of 60 kHz. A plot of the gain of this filter versus frequency is given in figure 3-6.

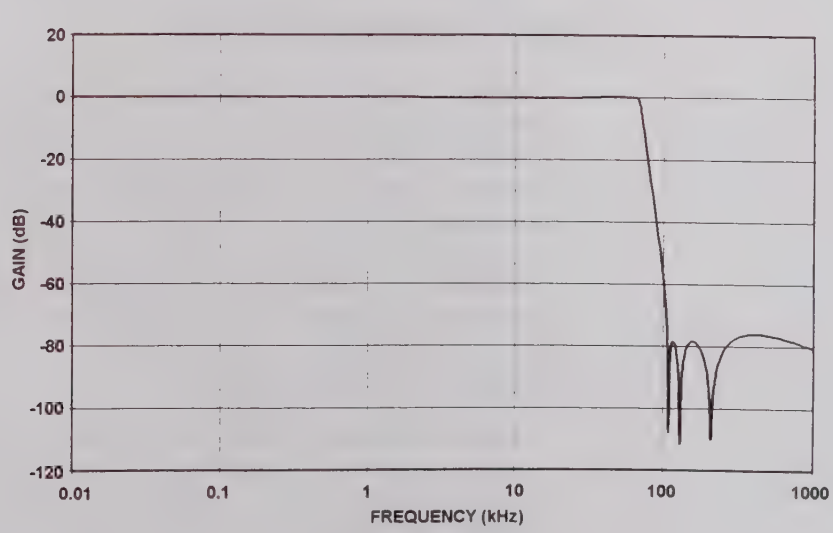


Figure 3-6, Anti-Alias Filter - Frequency Response

Although this filter shows some ripple in the passband, especially at frequencies above 30 kHz, a correction for the effect is applied in the main digital filter when using the bandpass mode (see section 3.3.07). For this reason, the bandpass mode is always recommended for use when measuring narrow-band signals.

If the main digital filter is set to the low-pass mode, then the effect of this ripple should be taken into account. However, since most of the ripple occurs at frequencies above the highest possible frequency setting of the digital filter, it is not generally a problem.

If the programmable digital filter measurement mode is set to flat (see section 3.3.07), then the anti-alias filter is bypassed.

A buffered version of the analog signal just prior to the main ADC is available at the **SIGNAL MONITOR** connector on the rear panel. This may be viewed on an oscilloscope to monitor the effect of the signal channel filters and amplifiers.

3.3.06 Main Analog-to-Digital Converter

Following the anti-alias filter the signal is digitized by the main 18-bit analog-to-digital converter running at a sampling rate of 200 kHz. The output from the converter feeds the digital signal processor, which implements the programmable digital filter and the True RMS - DC conversion stages.

3.3.07 Programmable Digital Filter

The digital filter provides the main noise-rejecting capability of the instrument and can be configured to operate in three modes. The bandpass mode is most commonly used and provides the best overall accuracy, whilst the low-pass mode is useful in cases where measurement over a wide bandwidth is required. The flat mode, in which the filter is disabled, is not generally recommended because this removes most of the noise-rejecting capability of the instrument. These modes are discussed in the following paragraphs.

Bandpass Mode
The bandpass filter has two controls, these being the center frequency, which may be set to values between 1 Hz and 60 kHz, and *Q*-factor, which can range from 2 to 100 in a 1-2-5 sequence. The filter comprises two second-order stages, giving an overall fourth-order response.

The term "*Q*-factor" is commonly used to specify the performance of a second-order bandpass filter and is related to its -3 dB bandwidth by the following equation:

$$\text{BANDWIDTH}_{-3dB} = \frac{\text{CENTER FREQUENCY}}{\text{Q - FACTOR}}$$

Hence, if the center frequency is 1000 Hz and the *Q*-factor is 2, then the -3dB bandwidth of a second-order filter will be 500 Hz.

The -3 dB bandwidth of each section of the filter is defined as above, but the -3 dB bandwidth of the overall filter is smaller. It is the latter value that is actually displayed as BW for each value of Q-factor, since the term "bandwidth" is commonly understood to imply the -3dB bandwidth of a complete filter rather than its individual elements. The value of BW is related to the Q-factor by the following equation:

$$BW_{-3dB} = \frac{\left(\sqrt{\sqrt{2}-1}\right) \times \text{CENTRE FREQUENCY}}{\text{Q-FACTOR}}$$

Hence in the example above, where the center frequency is set to 1000 Hz and the Q-factor to 2, the -3 dB bandwidth of a fourth-order filter, such as that in the model 7310, will be 321.7 Hz.

The effect on the bandwidth of changing the Q-factor is shown graphically in figures 3-7 and 3-8.

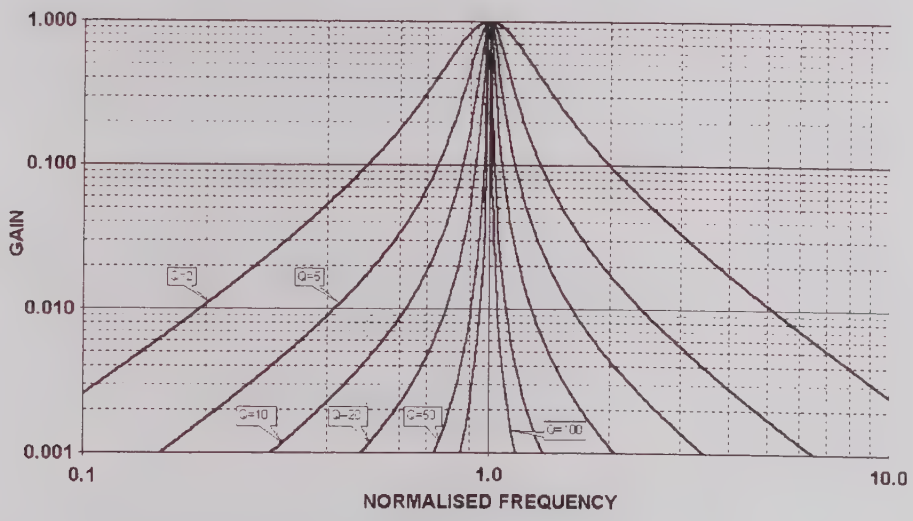


Figure 3-7, Bandpass Filter - Frequency Response

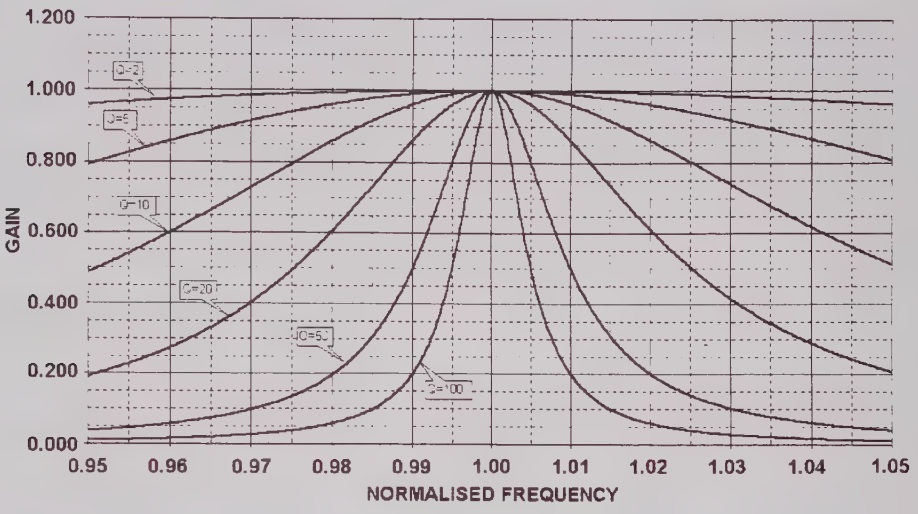


Figure 3-8, Bandpass Filter - Frequency Response

In a similar way to the plots for the line frequency rejection filter, the frequency axes are normalized to the bandpass filter frequency setting, so, for example, if the center frequency is set to 1000 Hz then figure 3-7 covers a frequency range of 100 Hz to 10 kHz, whilst figure 3-8 covers the range 950 Hz to 1050 Hz.

The plots clearly show that the higher the *Q*-factor, the greater the rejection of signals away from the set filter frequency. Users may therefore be tempted simply to set the *Q*-factor to its largest value of 100, on the basis that this will give the best performance. However, this will be true only if the frequency of the signal being measured is extremely stable and accurate, such as in the case of a crystal oscillator or source of similar stability. Many signals, which the user might wish to measure, will not have this level of frequency stability and accuracy, and a simple consideration of the above plots shows that large errors can be introduced by frequency shifts at high *Q*-factor settings. For example, if the *Q*-factor were set to 100, then it can be seen from figure 3-8 that a frequency change of only 1 % will cause the signal level to fall by 80 %.

Low-pass mode

In low-pass mode the filter is also a fourth-order Butterworth stage, but there is now only one control, this being the frequency at which the gain is 3 dB down (i.e. a factor of 0.7071) on the passband gain. This frequency may be set to values between 10 Hz and 28 kHz.

Figure 3-9 shows a plot of the frequency response of this filter, again with a normalized frequency axis.

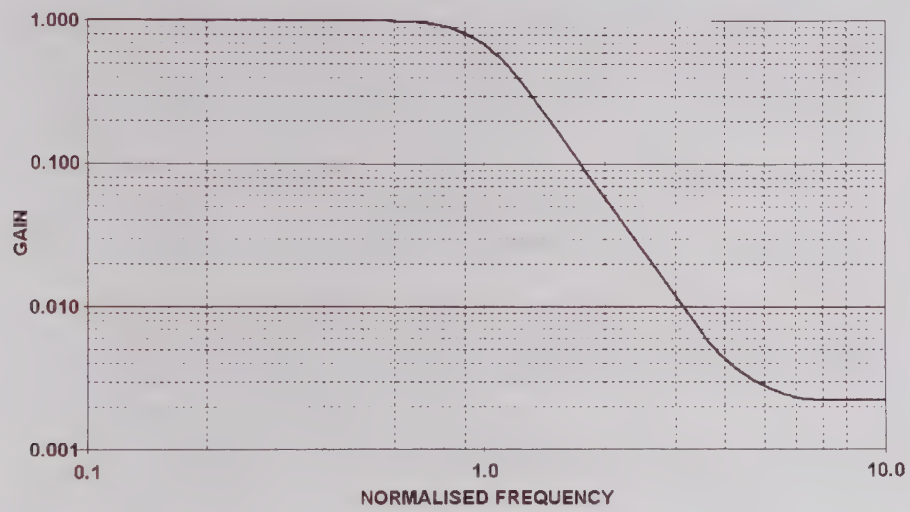


Figure 3-9, Low-Pass Filter - Frequency Response

Flat Mode

In the flat mode, the main digital filter and the analog anti-aliasing filter are inactive. It should be noted that this mode might give inaccurate measurements, due to input bandwidth limitations, if the input signal contains components with frequencies above 60 kHz.

Effect of Input Coupling and Anti-Alias Filters

As already mentioned, the frequency response of the instrument is affected not only by the digital filter but also, at low frequencies, by the effect of the AC-coupling at the input, and, at high frequencies, by the anti-aliasing filter. Hence the signal at the input to the True RMS-DC converter is in total affected by the following:-

1) High-pass roll-off caused by the AC-coupling of the input.
   This can be ignored if the signal being measured is greater than 2 Hz.

2) The line frequency rejection filter, if activated.

3) Low-pass roll-off caused by the anti-aliasing filter. This is not present in the following two cases:-

   a) When the digital filter is set to bandpass mode since the filter calibration corrects for it.

   b) When the digital filter is set to flat mode since the anti-alias filter is bypassed.

4) The programmable digital filter.

Consequently, in order to determine the instrument's rejection capability for any given interfering signal frequency, the effect of all these stages should be considered.

3.3.08 Filter Output

The digital signal output from the programmable filter, taken from the point prior to the RMS-DC conversion, is passed to a fast digital-to-analog converter (DAC), updated at the same rate as the main sampling process, i.e. 200 kHz. The DAC output is then filtered by a fourth-order Butterworth low-pass stage, which has a -3 dB cut-off frequency of 25 kHz, and appears at the **FILTER OUTPUT** connector on the rear panel.

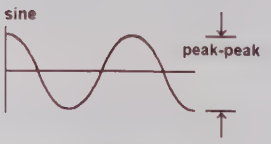
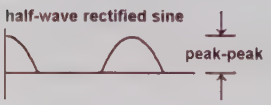
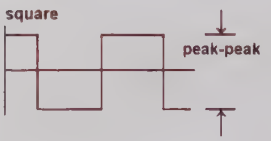
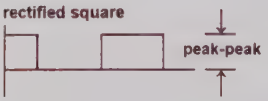
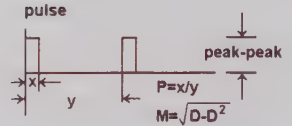
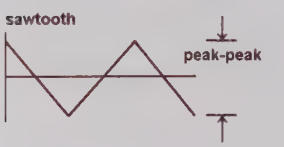
NOTE: The output is inactive when using the flat mode.

3.3.09 True RMS-DC Converter

The operation of the True RMS-DC converter shown on the block diagram in figure 3-1, depends on whether the instrument is in the AC or DC measurement mode. These modes are discussed in the following paragraphs.

DC measurement Mode
In the DC measurement mode the input signal amplifiers are DC-coupled, allowing DC signals to reach the analog-to-digital converter. The True RMS-DC converter is inactive, so the digitized values of the input signal pass straight through to the output filter, where they are averaged. Hence the instrument functions as a DC voltmeter with output averaging.

AC measurement Mode
In the AC measurement mode the input signal amplifiers are AC-coupled, allowing only AC signals to reach the analog-to-digital converter. The digitized signal then passes to the programmable digital filter, and thence to the True RMS-DC converter. This uses a numerical algorithm to determine the root-mean-square (r.m.s.) value of the digitized representation of the filtered input signal. The calculation generates a new result, every 1.25 ms, which is then transferred to the output filter, where it is averaged with earlier results. Hence, in Flat filter mode, the instrument functions as a true r.m.s. AC voltmeter with output averaging.

INPUT WAVEFORM	PEAK-PEAK VOLTAGE	AC RMS CAL METER (note 1)	MODEL 7310 MEASURED VOLTAGES		DC AND AC TRUE RMS $\sqrt{ac^2+dc^2}$
			DC Mode	AC Mode, FLAT filter setting (true RMS)	
sine 	2.828	1.000	0.000	1.000	1.000
full-wave rectified sine	1.414	0.421	0.900	0.435	1.000
half-wave rectified sine 	2.000	0.764	0.636	0.771	1.000
square 	2.000	1.110	0.000	1.000	1.000
rectified square 	1.414	0.785	0.707	0.707	1.000
pulse 	2.000	2.22 x M	2.0 x P	2.0 x M	$2 \times \sqrt{D}$
sawtooth 	3.464	0.960	0.000	1.000	1.000

Note 1: This is the value displayed on an average-responding meter calibrated to display RMS for sine waves.

Figure 3-10, Comparison of Peak, DC, AC Average, DC, AC R.M.S. and Total R.M.S. Values of Typical Waveforms

Traditional AC voltmeters use average-responding AC converters rather than the true r.m.s. conversion employed in the model 7310, which may lead to confusion when comparing the results of measurements made with the two types of instrument. Figure 3-10 therefore shows the relationship between a peak-to-peak voltage, the response of an averaging AC meter, the readings for both the DC and AC (Flat filter) measurement modes of the model 7310 and the total r.m.s. value for various common types of waveform.

For example, in the case of a 2 V peak-to-peak squarewave, with a mean about zero volts, the model 7310 operating in Flat filter mode will correctly indicate the r.m.s. value as 1.000 V whereas the traditional AC meter would indicate a value of 1.110 V.

It will be seen from figure 3-10 that in order to measure the true r.m.s. value of a waveform with a non-zero mean, using the model 7310, two measurements must be carried out. First, the instrument must be set to DC measurement mode and the mean, or DC, level determined and recorded. Then, the unit must be switched to AC measurement mode with the Flat filter setting and the AC true r.m.s. value measured. Finally, both readings should be combined using the following equation:-

$$V_{TOTAL\ RMS} = \sqrt{\left(V_{AC}^2 + V_{DC}^2\right)}$$

In some cases it is necessary to make measurements of a broadband signal with peak values much greater than the r.m.s. value. This situation typically arises with music signals (which are highly non-periodic) and also where the signal is periodic but non-sinusoidal, as in the case of a sequence of narrow pulses. For situations such as these it is necessary to take the shape of the input waveform into consideration and this is normally done by reference to its "crest factor".

The "crest factor" of a waveform is defined as follows:-

$$\text{CREST FACTOR} = \frac{\text{ZERO to PEAK VOLTAGE}}{\text{TRUE RMS VALUE}}$$

If the crest factor is greater than the instrument's crest factor limit, then it will not be possible to display a full-scale output without input overload.

The crest factor limit for the model 7310, when it is displaying a full-scale output (e.g. if it were measuring 200 mV r.m.s. on the 200 mV range), varies as a function of sensitivity range as shown in table 3-1.

Range	Crest Factor Limit
1 V	1.5
500 mV	3
200 mV	3
100 mV	6
≤ 50 mV	7.5

Table 3-1, Crest Factor Limit vs Range

Crest factors for typical waveforms are given in figure 3-11, from which it will be seen that the model 7310's crest factor limit will rarely cause a problem. In practice, waveforms with higher crest factors than the limits given in table 3-1 can usually be measured simply by choosing a less sensitive operating range.

If the crest factor of the waveform being measured is unknown, check that its AC r.m.s. value as measured by the model 7310 is greater than 1/(Crest Factor Limit) of

its zero-to-peak voltage as measured on an oscilloscope. If it is, and if all its relevant frequency components lie within the model 7310's measuring bandwidth, then the instrument will give an accurate reading.

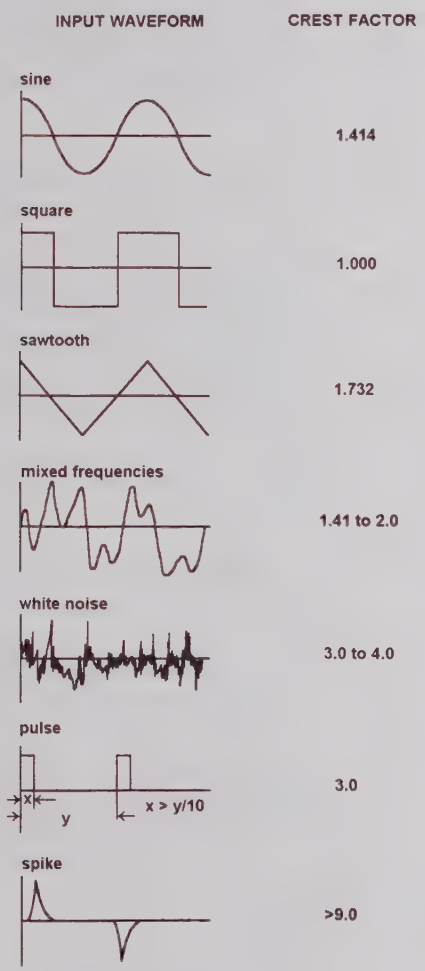


Figure 3-11, Crest Factors for Typical Waveforms

3.3.10 Output Smoothing

The output of the True RMS-DC converter is filtered by a low-pass filter stage to remove fluctuations in the displayed values. The filter has two controls, output smoothing time constant expressed in seconds, and slope, to give the maximum flexibility when setting its performance.

If the signal being measured is fluctuating with time about an unchanging average

value, then it can be difficult to read the digital display. In this case, the output smoothing time constant setting should be increased until a sufficiently steady reading is obtained. However, this also makes the instrument's response to a deliberate change in input signal slower. Consequently, if the user wishes the unit to "track" rapid changes in input signal level, then the output smoothing time constant setting should be reduced.

The slope is normally set to 12 dB/octave, except if the instrument is used as part of a feedback control loop. In this case, the loop may become unstable because of the phase-shift introduced by the output filter. In some cases, this condition can be avoided by setting the slope to 6 dB/octave.

3.3.11 Output Processor - General

Although shown on the block diagram as a separate entity, the output processor is in fact part of the instrument's main microprocessor. It takes the filtered main output and processes it to allow the display to show the measured signal both directly and in terms of a ratio, expressed in decibels, to a previously-entered level. This level may be entered manually or may be the result of an earlier measurement.

The processor also performs a user-defined calculation which can add, subtract, multiply or divide any combination of the main output, the voltage present on the **ADC1** and **ADC2** input connectors and two user specified constants.

Minimum and maximum level indicators are also maintained by the processor. These are reset either by application of the rising edge of a TTL pulse applied to the **RESET** connector on the rear panel, by pressing the **RESET** key on the front panel or by a computer command.

3.3.12 Output Processor - Output Offset

In certain cases the user may wish to measure changes in the signal in the presence of a steady interfering signal, the effect of which is to produce an offset in the displayed readings. The model 7310 has the ability to remove this offset, although the approach adopted depends on whether the DC or AC measurement mode is selected.

DC measurement Mode
The effect of a steady interfering DC signal is to produce a constant additional DC signal in the output. Hence the offset can be removed simply by subtracting a constant level from the output in the output processor.

AC measurement Mode
In the AC measurement mode, the squares of the two signals are added in the True RMS-DC converter as shown in the following equation. For example, if the output of the programmable digital filter before the True RMS -DC converter consisted of a required signal of 10 mV r.m.s. and an interfering signal at a different frequency of 5 mV r.m.s., then the total signal as displayed on the instrument would be

$$\text{TOTAL} = \sqrt{0.010^2 + 0.005^2}\ ,$$

or 11.18 mV r.m.s.. This represents an offset error of 1.18 mV.

If the required signal now increased to 20 mV, the displayed reading would rise to 20.616 mV, an error of 0.616 mV. Hence it is not possible simply to subtract a constant value from the output to compensate for the 5 mV interfering signal.

The problem is overcome in the model 7310 by allowing the user to add a constant value to the True RMS-DC converter at the point immediately before the square root is calculated. Since this level can be set to cancel the contribution of the interfering signal exactly, the offset can be removed at all levels of the required input signal.

Offset Operation
In either mode, to use the offset control, the true signal input should be switched off leaving the interfering signal unchanged. For example, in an optical application this could be done by blocking the light beam falling on the detector. The offset level is then either manually adjusted or automatically set by the Auto-Offset function until the displayed value is zero. The signal to be measured is then switched back on and the display will indicate the corrected value for the actual signal required.

One of the major advantages of the offset facility is obtained when the user needs to measure a signal whose frequency may vary over a small range. In this situation operation of the bandpass filter at high Q will not be practical because the signal may change frequency sufficiently to fall outside the very narrow bandpass imposed by this setting. Selecting a low value of Q will provide a suitable bandpass but may well allow a close interfering frequency to be included as output. Offsetting this interference as described above can dramatically improve the quality of the measurement.

3.3.13 Auxiliary Analog Inputs and Outputs (ADCs and DACs)

The model 7310 incorporates two auxiliary ADC inputs, which use conventional sample and hold converters giving a resolution of 1 mV in ±10.000 V. These inputs are normally employed for digitizing slowly-changing or DC signals, which are associated with a measurement, such as those generated by temperature and pressure transducers. The values can then be incorporated into the user-defined or ratio calculations, or transferred to a controlling computer. They may also be used in conjunction with the instrument's internal curve buffer to form a transient recorder operating at sample rates of up to 40 kHz.

Four auxiliary DAC analog outputs are also provided. These provide the same resolution as the ADCs, namely 1 mV in ±10.000 V.

3.3.14 Main Microprocessor - General

All functions of the instrument are under the control of a microprocessor which, in addition, drives the front panel display, processes front panel key operations and supports the RS232 and GPIB (IEEE-488) computer interfaces. This processor also drives the instrument's 8-bit digital (TTL) programmable output port, which may be used for controlling auxiliary equipment.

The microprocessor has access to a 32768 point memory which can be used for storage of selected instrument outputs as curves, prior to their transfer to a computer via the computer interfaces. In addition this function can also be used in conjunction with two of the auxiliary ADC inputs to allow the instrument to operate as a transient recorder.

A particularly useful feature of the design is that only part of the controlling firmware program code, which the microprocessor runs, is permanently resident in the instrument. The remainder is held in flash EEPROM and can be updated via the RS232 computer interface. It is therefore possible to change the functionality of the instrument, such as might be required by an original equipment manufacturer buying the instrument in quantity, simply by connecting it to a computer and running an update program.

3.3.15 Main Microprocessor - Auto Functions

The microprocessor also controls the instrument's auto functions, which are control operations executed by means of a single command or two key-presses. These functions allow easier, faster operation of the model 7310 in most applications, although direct manual operation or special purpose control programs may give better results in certain circumstances. During application of several of the auto functions, decisions are made on the basis of output readings made at a particular moment. Where this is the case, it is important for the output time constant set by the user to be long enough to reduce fluctuations in the output to a sufficiently low level so that valid decisions can be made and that sufficient time is allowed for the output to settle.

On completion of any of the auto functions the instrument display reverts to the Main Display.

The following sections contain brief descriptions of the auto functions.

Auto-Range
The Auto-Range function causes the full-scale sensitivity to be changed in steps until the output is less than 90 %, but more than 30 % of full-scale. After each change the instrument waits for a period of time to allow the outputs to settle prior to determining whether the required criterion is met.

In the presence of noise, or a time-varying input signal, it may be a long time before the Auto-Range sequence terminates, and the resulting setting may not be what is really required.

Auto-Set 0dB
The Auto-Set 0dB function sets the present measured signal level as the 0 dB level, which is used to calculate the dB output, and sets the Main Display to display this output type. Hence, for example, if the unit were displaying an output of 50 mV r.m.s. and the Auto-Set 0dB function were called, then the display would change to 0.000 dB. If the signal level then changed to 100 mV r.m.s. then this would appear as +6.02 dB in the dB mode.

Auto-Offset
In the DC measurement mode, the Auto-Offset function applies an offset in the output processor to reduce the output to zero. In the AC measurement mode, the offset is applied prior to the square root function in the True RMS-DC conversion stage to reduce the output to zero. The primary purpose of the facility is to allow the user to remove the effects of steady interfering signals from the measurement.
To use this function, the true signal input should be switched off leaving the interfering signal unchanged. The Auto-Offset function is then called, causing the displayed value to reduce to zero. The signal to be measured is then switched back on and the display will indicate the corrected value for the actual signal required.

Auto Default
With an instrument of complex design such as the model 7310, where there are many controls of which only a few are regularly adjusted, it is very easy to overlook the setting of one of them. Consequently an Auto-Default function is provided with two levels of operation. The full Auto-Default, as selected from the front panel or with a computer command, sets all the controls to a defined state, whilst the partial Auto-Default, available only via a computer command, produces the same state without affecting the communications interface settings. These functions are most often used as a rescue operation to bring the instrument into a known condition when it is giving unexpected results. A listing of the settings which are invoked by the use of these functions can be found in appendix F.

3.4 General

3.4.01 Accuracy

Assuming that neither the analog amplifiers nor the main analog-to-digital converter are overloaded and that the programmable digital filter is correctly tuned, then the absolute accuracy of the instrument is limited by the analog components in the signal channel, giving a resulting typical accuracy of ±0.2 percent of the full-scale sensitivity range.

3.4.02 Power-up Defaults

All instrument settings are retained when the unit is switched off. When the instrument is switched on again the settings are restored but with the following exceptions:-

a) The instrument is set to AC measurement mode.
b) The GPIB mask byte is set to zero.
c) The REMOTE parameter is set to zero (front panel control enabled).
d) The curve buffer is cleared.
e) The display backlight is turned on

Front and Rear Panels

Chapter 4

4.1 Front Panel

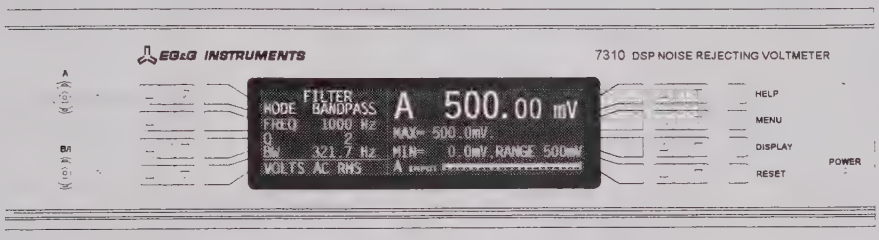


Figure 4-1, Model 7310 Front Panel Layout

As shown in figure 4-1 there are two BNC connectors with associated LED indicators, a 64 × 240 pixel, backlit LCD display panel, eight double and four single keys mounted on the model 7310's front panel. The following sections describe the function and location of these items.

4.1.01 A and B/I Signal Input Connectors

The **A** connector is the signal input connector for use in single-ended and differential voltage mode. The **B/I** connector is the signal input connector for use in differential voltage mode (**A-B**) and for inverting single-ended voltage mode (**B** mode). It is also the signal input connector when current input mode is selected. LEDs adjacent to the connectors light continuously to indicate which of them is active when a particular input mode is selected, or flash to indicate that the input is in overload (see figure 4-2).

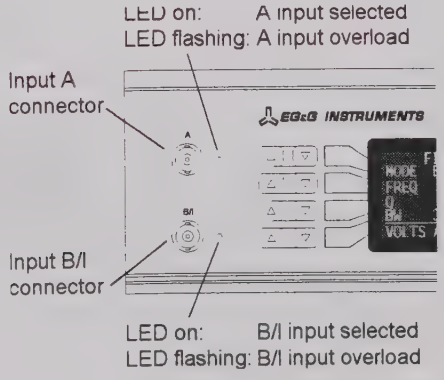


Figure 4-2, Signal Inputs

4.1.02 LCD Display Panel

This panel and the four pairs of keys on each side of it are used to adjust the instrument's controls and display the measured outputs, by means of a series of menus. The model 7310 is a sophisticated instrument with many features and consequently had a traditional design approach of using one button per control been implemented the front panel would have needed to be made very large. Adopting a menu-based control and display system, with the function of each key being dependent on the displayed menu, allows the instrument to be made much more compact and controls which need to be changed only occasionally to be hidden in normal use.

The eight pairs of keys have the following functions, depending on the displayed menu.

Function 1: To adjust the setting of a control.
If a control, such as the sensitivity range, filter mode or output smoothing time constant, is displayed on the screen then the adjacent (△)(▽) key pair is used to adjust its setting.

Some controls, such as the sensitivity range and output smoothing time constant, have only a limited range of settings, and so the use of the (△) and (▽) keys allows the required value to be chosen with only a few key-presses. Other controls, such as the digital filter frequency, digital to analog converter output voltages and offset level, can be set over a wide range of values and to a high precision. They are therefore adjusted by using a pop-up keypad which appears when needed on the right-hand side of the display and which operates as follows:-

Keypad Activation
Pressing either one of the (△)(▽) keys adjacent to a control requiring numerical entry causes a keypad to appear on the right-hand side of the display, as shown in figure 4-3. The twelve buttons displayed correspond to the twelve keys on the right-hand side of the instrument's front-panel.

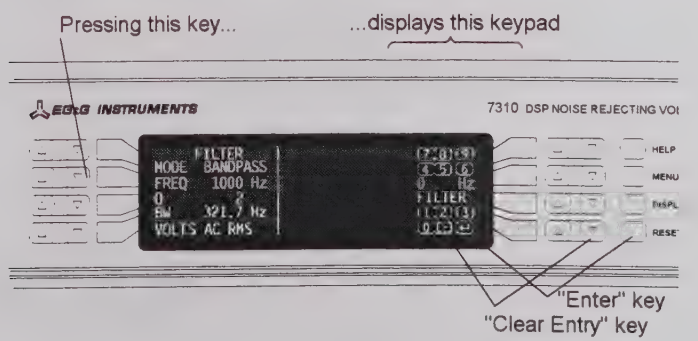


Figure 4-3, Numerical Entry Keypad

Use the keys to enter the required setting of the control. The name of the control and

the digits already entered appear in the middle section of the keypad as an aid to doing this. The (CE) (clear entry) key may be pressed at any time to clear any digits already entered. Once the required value is set, press the (↵) (enter) key to accept the value and remove the keypad.

Some controls may need to be set to non-integer values, in which case the (CE) key alternates with a (▪) (decimal point) key about once per second. To enter the decimal point simply ensure that it is displayed at the moment you press the corresponding key, and likewise to clear the entry. In a similar way, some controls may need to be set to negative values. In this case the (CE) alternates with the (±) (plus-minus) key.

As an example of this operation, suppose that the main digital filter center frequency is 1000 Hz and it is required to change it to 100.3 Hz. Press a key adjacent to the Main Display FREQ item. A keypad will appear on the right-hand side of the display.

Press the keys corresponding to the digits "1", "0", "0", (▪) and "3" to set the filter frequency to 100.3 Hz. Finally, press the (↵) key to accept the value and remove the keypad.

If the keypad is inadvertently activated, then the existing setting of the control can be retained without needing to re-enter it, as long as no digits have already been entered. This is done simply by pressing again the (△)(▽) keys on the left-hand side of the display that caused the keypad to appear.

Function 2: To Select a Menu or Sub-Menu
When the display adjacent to a (△)(▽) key pair displays a menu name, then pressing either the (△) or (▽) key selects that menu.

Function 3: To Execute a Pre-Programmed Function
When the display adjacent to a (△)(▽) key pair displays a pre-programmed function, such as Auto-Range or Auto Set 0dB, then pressing either the (△) or (▽) key executes that function.

Function 4: To Change the Displayed Output
When the Main Display is showing, the top and bottom (△)(▽) keys on the right-hand side of the display are used to select the output type displayed in the corresponding display position. The top pair allow the large digital indicator to be set to show the following signals:-

- Measured signal in volts or amps (volts or amps rms in the AC measurement mode)
- The ratio, expressed in decibels, of the measured signal to a preset level
- The DC voltage at either of the two auxiliary analog to digital converter inputs.

The bottom pair are used to set the corresponding display position to either a bar-graph or a small digit display of one of the same set of outputs, with the exception of the ratio option.

4.1.03 HELP Key

The model 7310 includes context-sensitive on-screen help. In many menus, pressing the **HELP** key followed by a key adjacent to any displayed control or menu selection provides information about that control or menu.

If information is required on other topics, then pressing **HELP** twice, when in the Main Display, accesses the main Help menu, from which the required subject may be obtained by pressing the relevant key.

To exit the Help screens and return to normal operation press the **HELP** key again.

4.1.04 MENU Key

The model 7310 is controlled by a series of on-screen menus. When the Main Display, which is used to adjust both the basic instrument controls and to display the measured signal, is shown the **MENU** key is used to access the Main Menu, from which other menus may be accessed. Pressing the **MENU** key a second time returns to the Main Display.

The structure of the menus is fully discussed in chapter 5.

4.1.05 DISPLAY Key

This key is used to cycle the front-panel display between the Main Display, normally used for adjusting the instrument controls and displaying the measured signal, the Spectral Display, useful for setting the filter frequencies, and the Large Digits Display, used for viewing from a distance. Each press of the key changes the display to the next selection.

4.1.06 RESET Key

This key is used to reset the maximum and minimum level indicators shown on the Main Display. Note that they are also reset on receipt of a positive-going pulse at the **RESET MAX/MIN** BNC connector on the rear panel. When the **RESET** key is pressed or a reset occurs, the indicators change to the present signal level and change from this set level as the signal increases or decreases thereafter.

4.2 Rear Panel

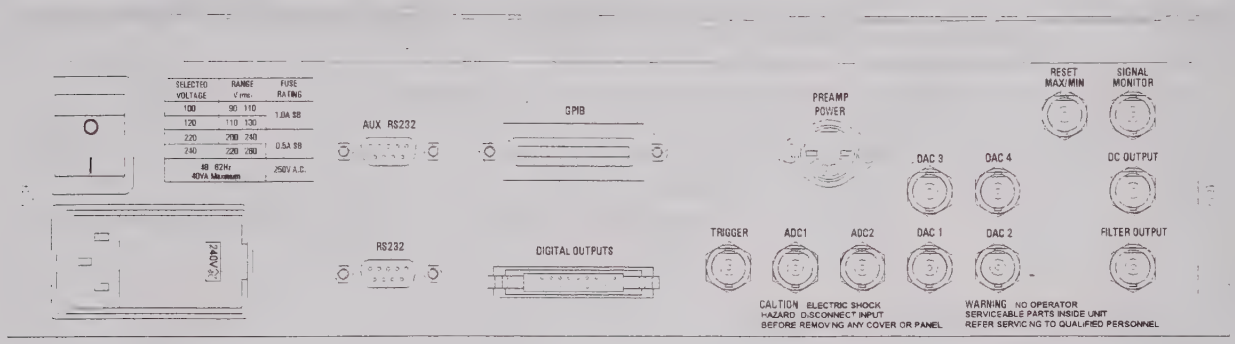


Figure 4-4, Model 7310 Rear Panel Layout

As shown in figure 4-4, the line power switch, line power voltage selector, two RS232 connectors, a GPIB (IEEE-488) connector, digital output port, preamplifier power connector and eleven BNC signal connectors are mounted on the rear panel of the instrument. Brief descriptions of these are given in the following text.

4.2.01 Line Power Switch

Press the end of the switch marked **I** to turn on the instrument's power, and the other end, marked **O**, to turn it off.

4.2.02 Line Power Input Assembly

This houses the line voltage selector and line input fuse. To check, and if necessary change, the fuse or line voltage see the procedure in section 2.1.05.

4.2.03 RS232 Connector

This 9-pin D type RS232 interface connector implements pins 1, 2, 3 and 7 (Earth Ground, Transmit Data, Receive Data, Logic Ground) of a standard DTE interface. To make a connection to a PC-compatible computer, it is normally sufficient to use a three-wire cable connecting Transmit Data to Receive Data, Receive Data to Transmit Data, and Logic Ground to Logic Ground. Appendix D shows the connection diagrams of cables suitable for computers with 9-pin and 25-pin serial connectors. Pinouts for this connector are given in appendix B.

4.2.04 AUX RS232 Connector

This connector is used to link other compatible EG&G equipment together in a "daisy-chain" configuration. Up to an additional 15 units can be connected in this way. Each unit must be set to a unique address (see section 5.3.13). Pinouts for this connector are given in appendix B.

4.2.05 GPIB Connector

The GPIB interface connector conforms to the IEEE-488 1978 Instrument Bus Standard. The standard defines all voltage and current levels, connector specifications, timing and handshake requirements.

4.2.06 DIGITAL OUTPUTS Connector

This connector provides eight TTL output lines, each of which can be set high or low by the use of the Digital Port menu or via the computer interfaces. It is most commonly used for controlling auxiliary apparatus, such as lamps, shutters and heaters. Pinouts for this connector are given in appendix B.

4.2.07 PREAMP POWER Connector

This connector supplies ±15 V at up to 100 mA and can be used for powering any of several optional remote preamplifiers available from EG&G. Pinouts for this connector are given in appendix B. Note that the instrument does not include any way of compensating for any external gain such as would be provided by an external preamplifier. Hence if a voltage preamplifier with a 60 dB gain (gain of ×1000) were used then the readings displayed on the model 7310 would need to be divided by 1000 in order to determine the signal levels at the preamplifier input.

4.2.08 RESET MAX/MIN Connector

This is a TTL-compatible input used to reset the maximum and minimum signal indicators. Reset occurs on the rising edge of any applied pulse.

4.2.09 SIGNAL MONITOR Connector

The signal at this connector is that immediately prior to the main analog to digital converter and after the preamplifier, line filter and anti-alias filters.

4.2.10 DC OUTPUT Connector

The signal at this connector is an analog voltage corresponding to a selected output, such as OUTPUT, RATIO, LOG RATIO, etc., as specified in the Output Channel menu. The full-scale output voltage range is ±10.0 V although the outputs remain valid to ±12.0 V to provide some overload capability.

4.2.11 TRIGGER Connector

This connector accepts a TTL-compatible input and can be used for triggering the auxiliary Analog to Digital Converters (ADCs) or for initiating curve storage. The input operates on the rising edge only.

4.2.12 ADC1 and ADC2 Connectors

The input voltages at these connectors may be digitized using the auxiliary ADCs and read either from the front panel or by the use of a computer command. The input voltages are sampled and digitized when the ADC is triggered, and several different

trigger modes are available. These modes can be set either from the front panel or by using a remote computer command. The input voltage range is ±10.0 V and the resolution is 1 mV.

4.2.13 DAC1, DAC2, DAC3 and DAC4 Connectors

There are four Digital-to-Analog Converter (DAC) output connectors. The output voltages at these connectors can be set either from the front panel or by the use of remote computer commands. The output range is ±10.0 V and the resolution is 1 mV.

4.2.14 FILTER OUTPUT Connector

The signal at this connector is an analog representation of the input signal after amplification, analog filtering by the line frequency rejection filter and anti-alias filters, digitizing and digital filtering by the main DSP filter. The output full-scale value is ±2.000 V corresponding to the set sensitivity range. Hence, for example, if the instrument is set to the 200 mV range with its digital filter set to bandpass mode and 1000 Hz, and a 1000 Hz sinusoidal signal of 100 mV is applied to its input, then the signal at this output will be a 1.000 V rms, or 2.828 V peak-to-peak, sinusoid.

The overload capability of the filter output is ±300 % for sensitivity ranges of 200 mV or greater, but only ±150 % for the 1 V and 500 mV ranges. The output -3dB bandwidth is 25 kHz, and hence the output amplitude is progressively attenuated as the frequency is increased above this value.

NOTE: The FILTER OUTPUT is inactive when using the FLAT mode.

Front Panel Operation

Chapter 5

5.1 Introduction

This chapter describes how to operate the model 7310 using the front panel controls, and discusses its capabilities when used in this way. Chapter 6 provides similar information in the situation where the unit is operated remotely using one of the computer interfaces.

It is assumed that readers are already familiar with the use of the ⟨△⟩ and ⟨▽⟩ keys on the front panel of the instrument, but if not then they should refer to the detailed description of their operation given in chapter 4.

The model 7310 uses a flexible, menu-based, control structure which allows many instrument controls to be adjusted from the front panel with only a few key-presses. Furthermore this design makes it very easy to introduce new features, or improve existing ones, without the restrictions which would result from a fixed front panel layout.

The following sections describe the menus, ranging from the Main Display, which is used most of the time for instrument control and display of data, through to those menus accessing controls which typically only need changing occasionally.

5.2 Menu Structure

Figure 5-1 shows the basic structure of the main instrument control menus which it will be seen has a hierarchical, or "tree", structure.

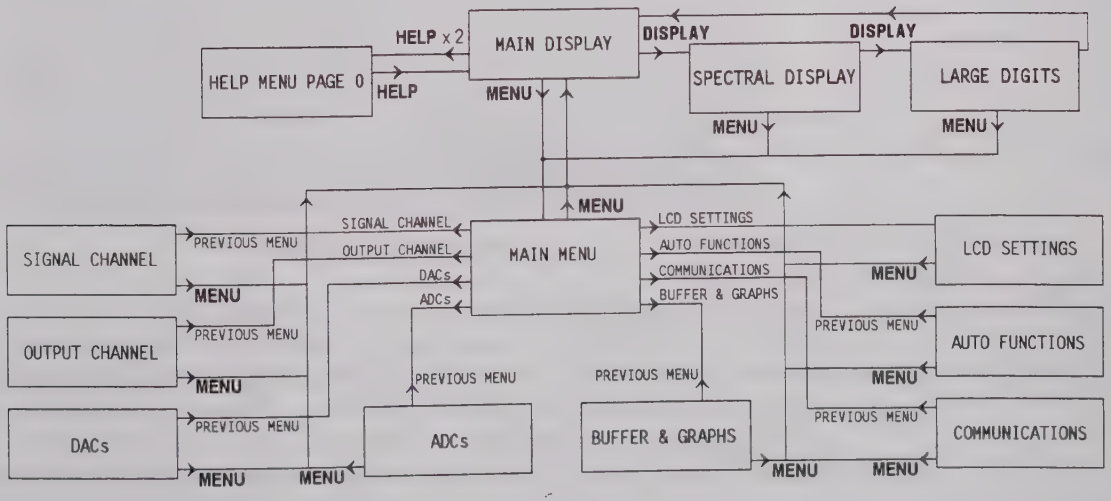


Figure 5-1, Main Menu Structure

In the diagram, although not in the rest of this manual, the following syntax is used:- The menus are shown as boxes, with menu names in light sans-serif typeface, e.g. MAIN MENU. Front-panel keys are shown in bold sans serif typeface, as they appear on the front panel of the instrument, e.g. **DISPLAY** and **MENU**. Arrows on the lines connecting the menus and the text adjacent to them indicate the keys which need to be pressed to move between menus.

The following examples should make this clear.

To access the Main Menu from the Main Display, press the **MENU** key on the front panel once; to return to the Main Display from the Main Menu, press the **MENU** key once again.

To access the Communications menu from the Main Display, press the **MENU** key on the front panel followed by a key adjacent to the word Communications shown in the Main Menu; to return to the Main Menu press a key adjacent to Previous Menu on the Communications menu.

Note that all menus, with the exception of the LCD Settings menu, provide a Previous Menu choice allowing the user to return one step up the menu "tree". In addition, when in any menu, except the two graphical displays, pressing the **MENU** key on the front panel provides a direct return to the Main Display.

Some menus, such as the Spectral Display and Buffer & Graphs menus, have further sub-menus which are discussed later. These have been omitted from figure 5-1 for the sake of clarity.

5.3 Menu Descriptions

5.3.01 Main Display

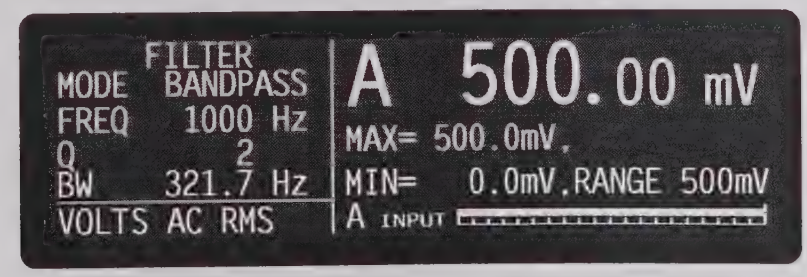


Figure 5-2, Main Display

The Main Display always appears on power-up and is similar to that shown in figure 5-2 above. It is divided into two sections by a single vertical line. Four instrument controls appear on the left-hand side, these being the main digital filter measurement mode, filter center frequency, filter "Q" (selectivity, and hence bandwidth) and the measurement mode. On the right-hand side, the measured signal is displayed in digital and/or bar-graph formats together with the minimum and maximum outputs since the last reset operation. Finally, the full-scale sensitivity range currently being used can

be adjusted using the control on the right-hand side of the display.

The selection of the output that is shown in the top and bottom right-hand display positions is made using the corresponding [△][▽] keys. The possible outputs for each display position are listed in table 5-1. In AC measurement mode, the signal level is expressed in volts or amps rms and in DC measurement mode, in volts or amps, in each case depending on whether voltage or current input mode is selected.

Top Right-hand Display:

Either

A	Signal level, after filtering, at the **A** input connector on the front panel.
B	Signal level, after filtering, at the **B** input connector on the front panel.
Δ	Differential signal voltage, after filtering, between the **A** and **B** input connectors on the front panel.

or, when the displayed unit is dB rather than volts or amps:-

A	Ratio of signal level, after filtering, at the **A** input connector on the front panel, to the preset 0 dB level, expressed in decibels.
B	Ratio of signal level, after filtering, at the **B** input connector on the front panel, to the preset 0 dB level, expressed in decibels.
Δ	Ratio of the differential signal voltage, after filtering, between the **A** and **B** input connectors on the front panel, to the preset 0 dB level, expressed in decibels.
ADC1	Voltage at the **ADC1** input connector on the rear panel, ±10.000 V full-scale.
ADC2	Voltage at the **ADC2** input connector on the rear panel, ±10.000 V full-scale.

Bottom Right-hand Display:

A INPUT	Signal level, after filtering, at the **A** input connector on the front panel, shown either as:- 1) Small digit digital display 2) Left-hand zero bar-graph - AC measurement mode only 3) Center zero bar-graph - DC measurement mode only.
B INPUT	Signal level, after filtering, at the **B** input connector on the front panel, shown either as:- 1) Small digit digital display 2) Left-hand zero bar-graph - AC measurement mode only 3) Center zero bar-graph - DC measurement mode only.
A-B INPUT	Differential voltage, after filtering, between the **A** and **B** input connectors on the front panel, shown either as:- 1) Small digit digital display 2) Left-hand zero bar-graph - AC measurement mode only 3) Center zero bar-graph - DC measurement mode only.
ADC1	Voltage at the **ADC1** input connector on the rear panel, ±10.000 V full-scale, center-zero bar-graph.
ADC2	Voltage at the **ADC2** input connector on the rear panel, ±10.000 V full-scale, center-zero bar-graph.

Table 5-1, Output Display Choices

NOTE: If the dB (decibels) display is used at the same time as DC measurement

mode then the input signal must be positive. Negative inputs cause a warning message to be displayed.

FILTER

The digital filter measurement mode is always displayed in the top left-hand corner of the Main Display and may be changed using the adjacent (△)(▽) keys. Three settings are provided, these being bandpass, low-pass and flat, the effects of which are discussed in section 3.3.07.

FREQ

When set to the low-pass mode, the FREQ control, which is used to set the digital filter -3 dB frequency to any value between 10 Hz and 28000 Hz, appears immediately below the mode control. When a (△)(▽) key adjacent to this item is pressed ,a pop-up keypad appears on the right-hand side of the display allowing the required value to be entered.

In the low-pass mode, the instrument measures the rms value of the signal at the input, within a bandwidth extending from the low frequency -3 dB cut-off point of the input AC-coupling circuit, to the upper -3 dB frequency of the digital filter defined by the FREQ setting.

FREQ
Q

When set to the bandpass mode, two controls appear immediately below the mode control. These are used to set the filter center frequency and *Q*-factor, or selectivity. The filter comprises two second-order stages, giving an overall fourth-order response.

The term "*Q*-factor" is a commonly used method of specifying the performance of a second-order bandpass filter and is related to its -3 dB bandwidth by the following equation:

$$\text{BANDWIDTH}_{-3dB} = \frac{\text{FREQ}}{\text{Q}}$$

Hence, if the center frequency is 1000 Hz and the *Q*-factor is 2 then the -3 dB bandwidth of a second-order filter will be 500 Hz.

The -3 dB bandwidth of each section of the filter is defined as above, but the -3 dB bandwidth of the overall (fourth-order) filter is smaller. It is the latter value that is actually displayed as BW for each value of *Q*-factor, since the term "bandwidth" is commonly understood to imply the -3 dB bandwidth of a complete filter rather than its individual elements. The value of BW is related to the *Q*-factor by the following equation:

$$\text{BW}_{-3dB} = \frac{\left(\sqrt{\sqrt{2}-1}\right) \times \text{FREQ}}{\text{Q}}$$

Hence in the example above of a center frequency of 1000 Hz and *Q*-factor of 2 then the -3 dB bandwidth of a fourth-order filter, such as that in the model 7310, will be 321.7 Hz.

In bandpass mode the filter center frequency may be set to a value between 1 Hz and 60 kHz and the *Q*-factor to any value between 2 and 100 in a 1-2-5 sequence. The instrument measures the rms value of the signal at the input, within a bandwidth derived from the *Q*-factor setting and the chosen center frequency. At low frequencies, the effect of the low frequency -3 dB cut-off point of the input AC-coupling circuit may need to be considered.

NOTE: Do not use high Q-factor settings unless the frequency of the signal being measured is both accurate and stable.

FLAT

If the filter mode is set to flat, then the instrument measures the rms value of the signal at the input, within a bandwidth extending from the low frequency cut-off point of the input AC-coupling circuit to the upper frequency cut-off point of the anti-aliasing filter.

AC VOLTS RMS / DC VOLTS AVG

The selected measurement mode of the instrument is indicated in the bottom left-hand position and can be changed between AC and DC modes simply by pressing the adjacent (△)(▽) keys. The two modes operate as follows:-

AC VOLTS RMS

In the AC measurement mode the signal input is AC-coupled and the instrument measures the true rms value of the input signal within a bandwidth defined by the digital filter. The signal amplitude may also be affected by the line frequency rejection filter, the input coupling and the anti-aliasing filter.

DC VOLTS AVG

In the DC measurement mode the signal input is DC-coupled and the instrument functions as an averaging DC voltmeter.

RANGE **(Full-scale sensitivity range)**

The range control, on the right-hand side of the display, allows the instrument's sensitivity to be adjusted.

AC Measurement Mode

When set to the voltage input mode, using the Signal Channel menu, the instrument's full-scale voltage sensitivity range may be set to any value between 10 μV and 1 V in a 1-2-5 sequence.

When set to the current input mode, using the Signal Channel menu, the instrument's full-scale current sensitivity may be set to any value between 10 pA and 1 μA, in a 1-2-5 sequence.

DC Measurement Mode
When set to the voltage input mode, using the Signal Channel menu, the instrument's full-scale voltage sensitivity range may be set to any value between 1 mV and 1 V in a 1-2-5 sequence.

When set to the current input mode, using the Signal Channel menu, the instrument's full-scale current sensitivity may be set to any value between 1 nA and 1 μA, in a 1-2-5 sequence.

Note that under overload conditions the control indicator "RANGE" is alternately shown in normal and reverse text, the LED(s) adjacent to the relevant input connector(s) flash and "OVL" (overload) appears above the display units. If this happens, reduce the signal level or increase the full-scale sensitivity range.

5.3.02 Spectral Display

When in the Main Display, press the **DISPLAY** key on the front panel once to access the Spectral Display, which is shown in figure 5-3.

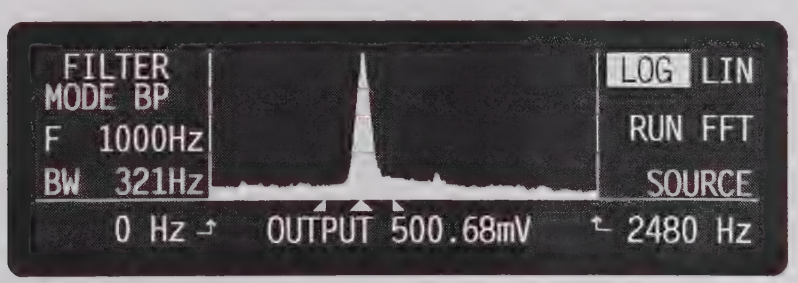


Figure 5-3, Spectral Display

The Spectral Display shows the result of a fast Fourier transform (FFT) of the signal at the input, following amplification and filtering by the line frequency rejection and anti-aliasing filters but prior to the programmable digital filter. Its principal use is to allow easy adjustment of the filter controls when the user is unsure as to the spectral content of the signal that is to be measured. Note that the Spectral Display does not have a calibrated vertical axis and hence is not intended for measuring or comparing signal amplitudes.

The central section of the display shows a plot of spectral density (vertical axis) versus frequency (horizontal axis). The upper and lower frequency limits are indicated in the bottom right-hand and left-hand display positions respectively, and may be increased or decreased using the corresponding △ ▽ keys. When the lower limit is changed, the upper limit changes by the same amount, thereby maintaining the frequency resolution, whereas when the upper limit is changed the frequency resolution is also changed. Consequently, any change to the upper limit causes the display to show "NO DATA" and the Run FFT key must be pressed again to take new data. Immediately under the spectral display the present level of the input signal, after passing through the digital filter, is shown in volts or amps rms. This allows the effect of any changes to the filter settings to be easily seen.

LOG LIN

The [△][▽] keys at the top right-hand corner of the display change the vertical display between linear and logarithmic calibration, with the currently active selection being shown in reverse text.

RUN FFT

When the [△][▽] keys adjacent to the Run FFT control are pressed, the instrument acquires a new set of data, performs an FFT on it and displays the resulting spectrum.

SOURCE

The FFT is carried out by acquiring a curve of the digitized input signal versus time into a buffer. This curve is then used as a source of data for a numerical algorithm which calculates a discrete Fourier transform. For the purposes of providing a spectral display and an aid to instrument set-up this may be considered as being similar to an FFT.

If the [△][▽] keys adjacent to the Source control are pressed then the contents of the curve buffer may also be displayed in a graphical format, similar to that used in the Single Graph menu discussed later in section 5.3.21, allowing the user to check that the acquired signal does not contain any unexpected waveforms.

FILTER MODE

F (Filter Frequency)

BW (Filter Bandwidth)

On the left-hand side of the display, the filter mode control, filter frequency and filter -3 dB bandwidth controls are displayed. These affect the digital filter in the same way as the controls on the Main Display, except that pressing a key next to the filter frequency display does not cause a pop-up keypad to appear. Instead, the filter frequency is changed by an increment defined by the following equation:-

$$\text{Frequency Increment} = \frac{\text{Upper Frequency Limit - Lower Frequency Limit}}{124}$$

The center or the upper frequency of the filter (depending on whether bandpass or low-pass mode is selected) is indicated by a small cursor positioned immediately below the x-axis. In bandpass mode the bandwidth is indicated by two additional cursors located either side of the center frequency cursor. As the filter controls are adjusted the position of these cursors change to reflect the new settings. Note that pressing a key adjacent to the BW control actually adjusts the *Q*-factor of the filter, as described under Main Display, and the display shows the bandwidth resulting from this selection.

In a typical measurement, the spectrum of the signal to be measured is first determined and displayed using the Spectral Display. The filter is then set to either bandpass or low-pass mode, and its center frequency and/or bandwidth adjusted using the filter frequency "F" and bandwidth "BW" [△][▽] keys. As this is done, the displayed rms value of the signal being measured is constantly updated, allowing optimum setting of these controls. Finally, the display is returned to the Main Display

by pressing the **MENU** key and the required output type (e.g. rms or dB level) selected.

5.3.03 Large Digits Display

When in the Main Display, press the **DISPLAY** key on the front panel twice to access the Large Digits Display, which is shown in figure 5-4.

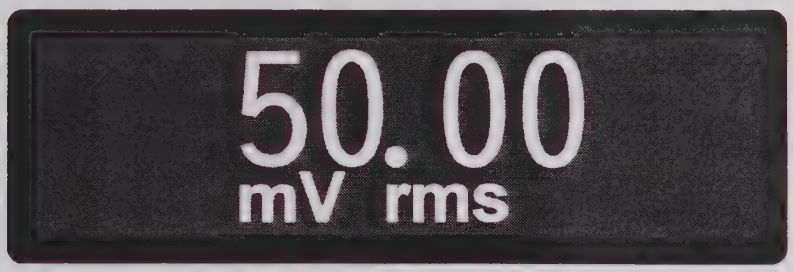


Figure 5-4, Large Digits Display

The Large Digits Display shows the same data as that displayed in the upper right-hand side of the Main Display, but in a larger format suitable for reading from a distance. None of the eight (△)(▽) keys adjacent to the display are active in this mode, and hence if the user wishes to change the displayed output then this must be done by returning to the Main Display.

Under overload conditions the word OVERLOAD appears in flashing text in the bottom left-hand corner of the display.

It will be appreciated from figure 5-1 that the **DISPLAY** key on the front panel is used to cycle through the three possible output displays, and hence to return to the Main Display from the Large Digits Display simply press the **DISPLAY** key once.

5.3.04 Main Menu

When in the Main Display, press the **MENU** key on the front panel once to access the Main Menu, which is shown in figure 5-5.

Figure 5-5, Main Menu

The Main Menu is used to access all of the remaining instrument controls via a series of sub-menus, which are selected simply by pressing a key adjacent to the required

menu. The sub-menus are described in the following sections.

5.3.05 Signal Channel Menu

When the Main Menu is displayed, pressing a key adjacent to the Signal Channel item accesses the Signal Channel menu, which is shown in figures 5-6 and 5-7. The appearance of the menu depends on whether voltage or current input mode is presently active.

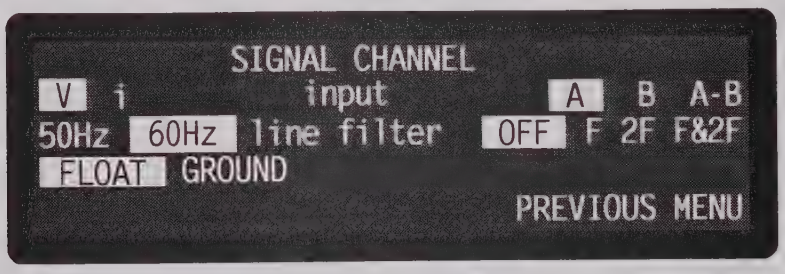


Figure 5-6, Signal Channel Menu - Voltage Input Mode

Figure 5-7, Signal Channel Menu - Current Input Mode

The Signal Channel menu has five controls affecting the instrument's signal input channel. Changes to the setting of these controls can be made by using the adjacent (△)(▽) keys, with the currently active selection being highlighted.

Input
The input control is used to select voltage or current input mode and, in voltage mode, the input connector(s) which will be used.

V (Voltage input mode)
In this setting the signal channel input is a voltage input, and the menu appears as in figure 5-6. It is connected according to the setting of the corresponding right-hand input control, as follows:-

A
The signal channel input is a single-ended voltage input to the BNC connector on the front panel marked **A**.

B
The signal channel input is an inverting, single-ended voltage input to the BNC connector on the front panel marked **B/I**.

A-B
In this setting the signal channel input is a differential voltage input connected to the BNC connectors on the front panel marked **A** and **B/I**.

i **(Current input mode)**
In this setting the signal channel input is a current input, and the menu appears as in figure 5-7. The signal is applied to the **B/I** connector on the front panel, as indicated by the letter "B" shown in reverse text on the "input" line of the display.

Line Filter
These two controls select the center frequency of the line frequency rejection filter and allow the filter to be switched in or out of use. Operation is as follows:-

50Hz
When shown in reverse text, sets the center frequency of the line frequency rejection filter to 50 Hz. Use this setting in countries with a 50 Hz line (mains) frequency.

60Hz
When shown in reverse text, sets the center frequency of the line frequency rejection filter to 60 Hz. Use this setting in countries with a 60 Hz line (mains) frequency.

NOTE: New instruments are supplied from the factory with the filter frequency set to 60 Hz. However if the unit is to be used in a 50 Hz region then the setting of this control will need to be changed.

The filter mode is controlled by the right-hand line filter control, and offers four possible settings as defined by the following table, with the presently active one being indicated in reverse text:-

Legend	Function
OFF	Line filter inactive
F	Enable 50 or 60 Hz notch filter
2F	Enable 100 or 120 Hz notch filter
F&2F	Enable both filters

Graphical plots of filter gain versus frequency for each of the three settings when the filter is in use are given in section 3.3.03.

Coupling
This control is used to select the coupling mode of the input connectors as follows:-

FLOAT
The shells of the **A** and **B/I** connectors are connected to chassis ground via a 1 kΩ resistor.

GROUND
The shells of the **A** and **B/I** connectors are connected directly to chassis ground.

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.3.06 Output Channel Menu

When the Main Menu is displayed, pressing a key adjacent to the Output Channel item accesses the Output Channel menu, which is shown in figure 5-8.

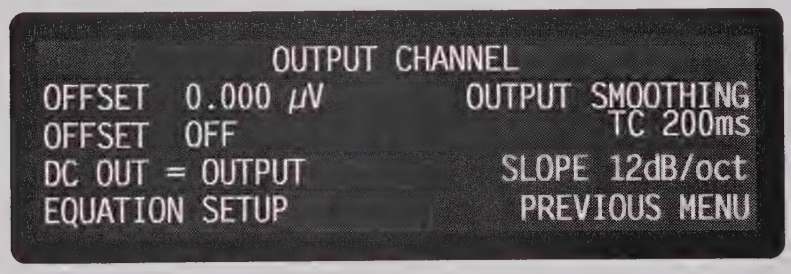


Figure 5-8, Output Channel Menu

The Output Channel menu has five controls affecting the instrument's outputs and a key used for accessing the Equation Setup menu. Changes to the setting of the controls can be made by using the adjacent (△)(▽) keys.

OFFSET (upper line)
This control allows manual adjustment to the value of the offset which is applied prior to the RMS-DC conversion. When the control is activated, a display similar to the Main Display appears and offers the option of performing an Auto-Offset operation or entering a level manually using a pop-up keypad. Note that the offset is only applied if the offset is switched on, using the offset status control (see below).

The value is set automatically by the Auto-Offset function, which also automatically switches the offset status to "on".

OFFSET (lower line)
This control specifies the offset status and allows the offset, set by the level control, to be switched on or off. When turned on, the indication and the offset level label appear in reverse text, and the letters "OFS" appear above the units of the digital meter on the main display as a warning to users that offset is enabled.

DC OUT
This control is used to specify which one of the possible instrument outputs is converted to an analog voltage and made available at the **DC OUTPUT** connector on the rear panel. It has five settings, as follows:-

OUTPUT
When set to OUTPUT the **DC OUTPUT** connector on the rear panel will output a voltage related to the displayed reading and the present full-scale sensitivity range as defined by the following equation:-

$$\text{DC OUTPUT} = 10 \times \frac{\text{DISPLAYED READING}}{\text{SENSITIVITY RANGE}} \text{ volts}$$

Hence, for example, if the instrument were displaying a signal level of 50 mV when set to the 500 mV sensitivity range, then the output voltage would be 1 V. Note that the maximum DC Output voltage is ±12.000 V

dB OUTPUT

When set to dB OUTPUT the **DC OUTPUT** connector on the rear panel will output a voltage related to the displayed reading in decibels as defined by the following equation:-

$$\text{DC OUTPUT} = \frac{\text{DISPLAYED READING (dB)}}{10} \text{ volts}$$

Hence, for example, if the instrument were displaying a signal level of +100 dB then the output voltage would be 10 V. Note that the range of DC Output voltages is +10.000 V to -6.000 V

RATIO

When set to RATIO the **DC OUTPUT** connector on the rear panel will output a voltage related to the displayed reading, present full-scale sensitivity range and the voltage applied to the **ADC1** connector on the rear panel as defined by the following equation:-

$$\text{DC OUTPUT} = 10 \times \frac{\left(\frac{\text{DISPLAYED READING}}{\text{SENSITIVITY RANGE}}\right)}{\text{ADC1 VOLTAGE}} \text{ volts}$$

Hence, for example, if the instrument were displaying a signal level of 50 mV when set to the 500 mV sensitivity range, with a 2 V DC signal applied to the **ADC1** input connector, then the output voltage would be 0.5 V. Note that the maximum DC Output voltage is ±12.000 V

LOG RATIO

When set to LOG RATIO the **DC OUTPUT** connector on the rear panel will output a voltage related to the rms signal level, present full-scale sensitivity range and the voltage applied to the **ADC1** connector on the rear panel as defined by the following equation:-

$$\text{DC OUTPUT} = \log_{10}\left(10 \times \frac{\left(\frac{\text{DISPLAYED READING}}{\text{SENSITIVITY RANGE}}\right)}{\text{ADC1 VOLTAGE}}\right) \text{volts}$$

Hence, for example, if the instrument were displaying a signal level of 50 mV when set to the 500 mV sensitivity range, with a 2 V DC signal applied to the **ADC1** connector, then the output voltage would be -0.301 V. Note that the maximum DC Output voltage in this mode is ±3.000 V and that if RATIO < 0 then LOG RATIO = -3.000 V.

EQUATION
When set to EQUATION the **DC OUTPUT** connector on the rear panel will output a voltage related to the Equation, which is defined using the Equation Setup menu (see section 5.3.07), as follows:-

EQUATION	DC OUTPUT Voltage
+10000	10.0 V
0	0.0 V
-10000	-10.0 V

OUTPUT SMOOTHING TC
This control is used to set the output smoothing time constant to any value between 5 ms and 10 s in a 1-2-5 sequence. The control should be set to the minimum value which gives the required display stability. The settling time, following any change in input signal, is twice the displayed time if the slope is 6 dB/octave and four times the time if the slope is 12 dB/octave.

SLOPE
The roll-off of the output filter is set, using this control, to either 6 dB/octave or 12 dB/octave. Normally the 12 dB/octave setting is used, but if the user wishes to monitor rapid changes in the input signal level, or incorporate the instrument as part of a feedback control loop, then the 6 dB/octave setting will give better results.

EQUATION SETUP
Pressing a key adjacent to the Equation Setup item accesses the menu used to define the user-specified equation, discussed in the following section (5.3.07).

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.3.07 Equation Setup Menu

When the Output Channel Menu is displayed, pressing a key adjacent to the Equation Setup item accesses the Equation Setup menu, which is shown in figure 5-9.

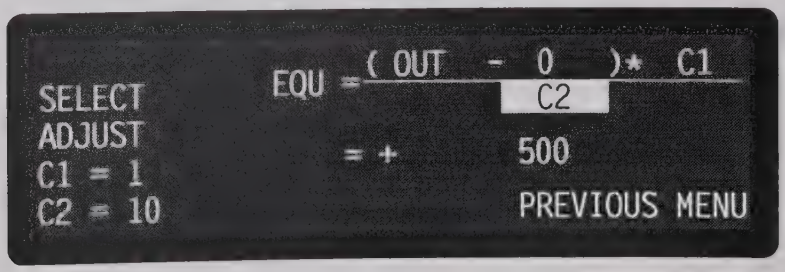


Figure 5-9, Equation Setup Menu

The Equation Setup menu is used to define more complex calculations on the instrument outputs than are possible using the basic ratio and log ratio options. The equation takes the following form:-

$$\text{Equation} = \left(\frac{(A \pm B) \times C}{D} \right)$$

where the operator "±" may be set to either addition or subtraction, and the variables A, B, C and D can be chosen from the following list:-

Variable	Range
OUT	±30000
ADC1	±10000
ADC2	±10000
C1	0 to 99999
C2	0 to 99999
0	zero
1	unity

The OUT, ADC1 and ADC2 values are calculated according to the following equations:-

$$\text{OUT} = 10000 \times \frac{\text{DISPLAYED READING}}{\text{SENSITIVITY RANGE}}$$

$$\text{ADC1} = 1000 \times \text{ADC1 VOLTAGE}$$

$$\text{ADC2} = 1000 \times \text{ADC2 VOLTAGE}$$

The select [△][▽] keys are used to highlight the required variable, and the adjust [△][▽] keys are used to change it.

The values C1 and C2 are user-defined integer constants and are adjusted using the two controls on the lower left-hand side of the display which cause a pop-up keypad to appear allowing direct numerical entry of the required values.

The calculation is performed using 64-bit integers to maintain full accuracy through to the 32-bit result that is displayed immediately below the equation and is constantly updated. Care must be taken in defining the equations so as to make the best use of the available output range.

If the equation output is specified, using the Output Channel menu, as the output to appear at the **DC OUTPUT** connector on the rear panel, then the output values should be adjusted to lie in the range -10000 to +10000. Values outside this range will result in the analog output limiting at ±10.000 V, although the digital value will still appear correctly on the display and can be read via the computer interfaces.

Note that the equation continues to be calculated even when the Equation Setup menu is not displayed.

Pressing a key adjacent to the Previous Menu item returns control to the Output Channel menu.

5.3.08 DACs Menu

When the Main Menu is displayed, pressing a key adjacent to the DACs item accesses the DACs menu, which is shown in figure 5-10.

Figure 5-10, DACs Menu

The DACs menu has four controls which are used to set the voltages appearing at the **DAC1, DAC2, DAC3 & DAC4** connectors on the rear panel.

DAC1, DAC2, DAC3 and DAC4

These four controls set the voltages, appearing at the **DAC1, DAC2, DAC3** or **DAC4** connectors on the rear panel, to any value between -10.000 V and +10.000 V in 1 mV increments. When a [△][▽] key adjacent to any of the level indicators is pressed, a pop-up keypad appears on the right-hand side of the display allowing direct entry of the required voltage.

The keypad operates in the same way as the other pop-up keypads, except that it may also be used to specify a voltage increment by which any of the DACs can then be changed. This is done as follows:

1) Press a [△][▽] key adjacent to the required DAC output level indicator. The pop-up keypad appears on the right-hand side.

2) Enter the voltage increment required using the keypad, but do not press the [↵] (enter) key.

3) Press a [△][▽] key adjacent to the same DAC output level indicator as in step 1) above. The text above the lower half of the keypad changes to "INC/DEC" (increment/decrement) indicating that the specified voltage is the voltage increment by which any of the DAC outputs may now be adjusted.

4) The voltage at each of the DAC outputs may now be changed by the specified increment using the corresponding [△][▽] keys.

5) When all DAC voltages are set as required, press the ↵ (enter) key to remove the keypad display.

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.3.09 ADCs Menu

When the Main Menu is displayed, pressing a key adjacent to the ADCs item accesses the ADCs menu, which is shown in figure 5-11.

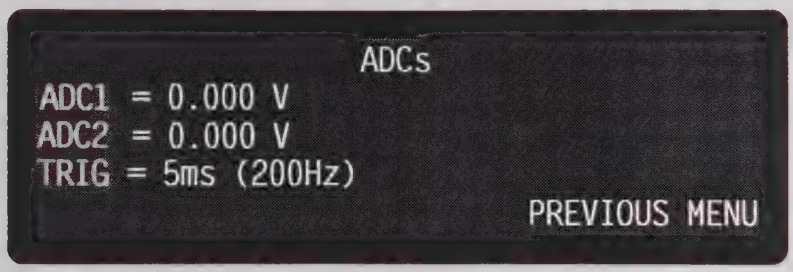


Figure 5-11, ADCs Menu

The ADCs menu has one control, which is used to set the trigger mode for the analog to digital conversion of the voltages applied to the **ADC1** and **ADC2** connectors on the rear panel, and two displays for the present value of these two voltages.

TRIG **(ADC Trigger Mode Control)**
This has ten possible settings, as follows:-

5ms (200Hz)
A conversion is performed on both ADC1 and ADC2 once every 5 ms. The results of the conversions are displayed on the ADCs menu and are available via the computer interfaces.

EXTERNAL (RP)
A conversion is performed on both ADC1 and ADC2 on receipt of a rising edge at the TTL **TRIGGER INPUT** connector on the rear panel. The maximum trigger rate is 400 Hz. The results are displayed on the ADCs menu and are available via the computer interfaces.

BURST ADC1
A burst of conversions at approximately 40 kHz is performed on ADC1 only, either on receipt of the TADC2 computer command or when the Trigger Burst Mode key is pressed. The results are stored to the curve buffer, with the number of conversions being set by the curve length control on the Curve Buffer menu - see section 5.3.19.

BURST ADC1&2
A burst of conversions at approximately 20 kHz is performed on both ADC1 and ADC2, either on receipt of the TADC3 computer command or when the Trigger Burst Mode key is pressed. The results are stored to the curve buffer, with the

number of conversions being set by the curve length control on the Curve Buffer menu - see section 5.3.19.

BURST ADC1 (T)
This is the same as the BURST ADC1 mode, except that the sampling rate may be set using the Rate control and the computer command to initiate acquisition is TADC4.

BURST ADC1 & 2 (T)
This is the same as the BURST ADC1 & 2 mode, except that the sampling rate may be set using the Rate control and the computer command to initiate acquisition is TADC5.

BURST ADC1 (RP)
This is the same as the BURST ADC1 mode, except that acquisition is initiated on receipt of a rising edge at the TTL **TRIGGER INPUT** connector on the rear panel.

BURST ADC1 & 2 (RP)
This is the same as the BURST ADC1 & 2 mode, except that acquisition is initiated on receipt of a rising edge at the TTL **TRIGGER INPUT** connector on the rear panel.

BURST ADC1 (RP T)
This is the same as the BURST ADC1 (T) mode, except that acquisition is initiated on receipt of a rising edge at the TTL **TRIGGER INPUT** connector on the rear panel.

BURST ADC1 & 2 (RP T)
This is the same as the BURST ADC1 & 2 (T) mode, except that acquisition is initiated on receipt of a rising edge at the TTL **TRIGGER INPUT** connector on the rear panel.

NOTE: When any of the burst acquisition modes are selected, the instrument automatically changes the curves selected for storage, as shown on the Curve Select menu (section 5.3.20), to be either ADC1 or ADC1 and ADC2.

TRIGGER BURST MODE
When one of the triggered burst modes is selected, this control is displayed. Press a key adjacent to it to trigger data acquisition.

RATE
When one of the timed burst modes is selected, the rate control is active. The number displayed, n, sets the sample rate according to the following equations:-

When storing only to ADC1:
(i.e. BURST ADC1 (T), BURST ADC1 (RP) and BURST ADC1 (RP T)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 157} \right) \text{Hz}$$

When storing to ADC1 and ADC 2:
(i.e. BURST ADC1 & 2 (T), BURST ADC1 & 2 (RP) and
BURST ADC1 & 2 (RP T)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 1031} \right) \text{Hz}$$

For convenience, the result of this calculation is shown on the display and so, for example, when n = 20, the sample rate will be 24,353 Hz for ADC1.

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.3.10 LCD Settings Menu

When the Main Menu is displayed, pressing a key adjacent to the LCD Settings item accesses the LCD Settings menu, which is shown in figure 5-12.

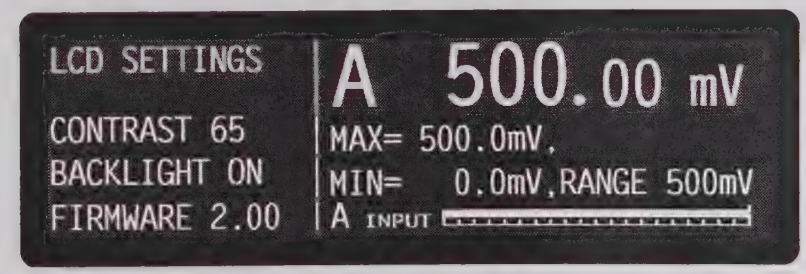


Figure 5-12, LCD Settings Menu

This menu has two controls affecting the instrument's display, as follows:-

CONTRAST
This control adjusts the contrast of the LCD display panel.

BACKLIGHT
This control allows the instrument's LCD display panel backlight and the LEDs on the front panel to be switched on or off.

FIRMWARE
The number reported here is the version of firmware fitted in the instrument. The firmware may be updated by connecting the instrument to a PC-style computer via the RS232 interface and then running a firmware update program.

Press the **MENU** key on the front panel to return to the Main Display from the LCD Settings menu.

5.3.11 Auto Functions Menu

When the Main Menu is displayed, pressing a key adjacent to the Auto Functions item accesses the Auto Functions menu, which is shown in figure 5-13.

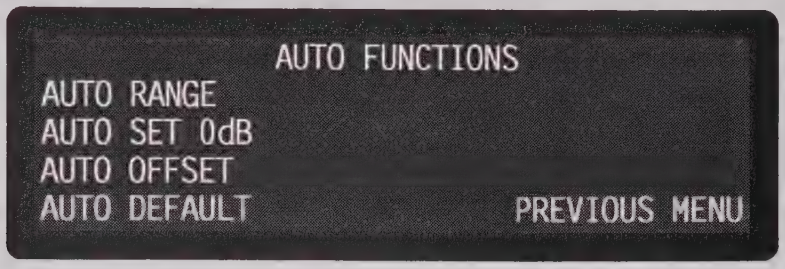


Figure 5-13, Auto Functions Menu

This menu has four controls for activating the auto functions built into the instrument. Note that once these functions complete, the Auto Functions menu is replaced by the Main Display. The functions operate as follows:-

AUTO-RANGE

The Auto-Range function causes the sensitivity range to be changed in steps until the output is less than 90 %, but more than 30 %, of full-scale. After each change the instrument waits for a period of time to allow the outputs to settle prior to determining whether the required criterion is met.

In the presence of noise, or a time-varying input signal, it may be a long time before the Auto-Range sequence terminates, and the resulting setting may not be what is really required.

AUTO-SET 0dB

The Auto-Set 0dB function sets the present measured signal level as the 0 dB level, which is used to calculate the dB output when this is chosen for display, and turns on the dB display mode. Hence, for example, if the unit were displaying an output of 50 mV and the Auto-Set 0dB function were called, then the same value would be displayed as 0.000 dB when the function completed. If the signal level then changed to 100 mV then this would appear as +6.02 dB in the dB mode.

AUTO-OFFSET

In the DC measurement mode, the Auto-Offset function applies an offset in the output processor to reduce the output to zero. In the AC measurement mode, the offset is applied prior to the square root function in the True RMS-DC conversion stage to reduce the output to zero. The primary purpose of the facility is to allow the user to remove the effects of steady interfering signals from the measurement.

To use this function, the true signal should be switched off leaving the interfering signal unchanged. The Auto-Offset function is then called, causing the displayed value to reduce to zero. The signal to be measured is then switched back on and the display will indicate the corrected value for the actual signal.

AUTO-DEFAULT

With an instrument of the design of the model 7310, where there are many controls of which only a few are regularly adjusted, it is very easy to overlook the setting of one of them. Consequently an Auto-Default function is provided to set all of the controls to a defined state. This is most often used as a rescue operation to bring the

instrument into a known condition when it is giving unexpected results. A listing of the settings which are invoked by the use of this function can be found in appendix F.

Pressing a key adjacent to the Previous Menu item returns control to the Main Menu.

5.3.12 Communications Menu

When the Main Menu is displayed, pressing a key adjacent to the Communications item accesses the Communications menu, which is shown in figure 5-14.

Figure 5-14, Communications Menu

The Communications menu is used to access five sub-menus, the relationship of which to the Communications menu is shown in figure 5-15. Note that as with the main menu structure, shown in figure 5-1, it is possible to return to the Main Display from any menu by pressing the **MENU** key on the front panel, but this has been omitted from figure 5-15 for the sake of clarity.

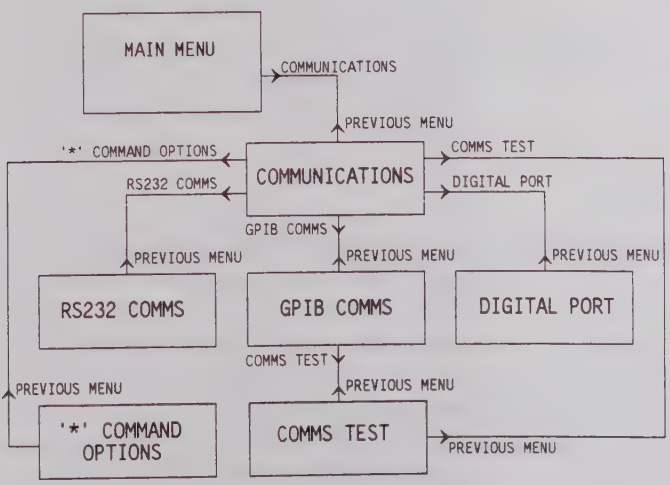


Figure 5-15, Communications Menu Structure

5.3.13 RS232 Comms Menu

When the Communications menu is displayed, pressing a key adjacent to the RS232 Comms item accesses the RS232 Comms menu, which is shown in figure 5-16.

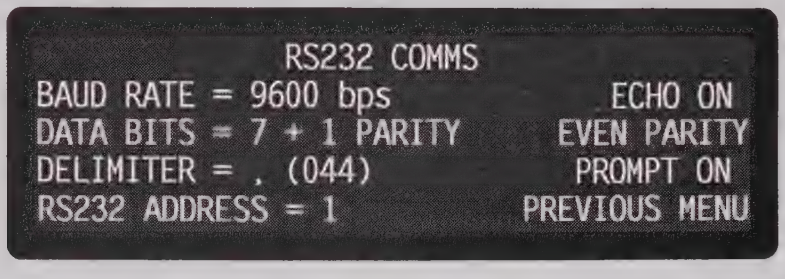


Figure 5-16, RS232 Comms Menu

This menu has seven controls affecting the RS232 computer interface, as follows:-

BAUD RATE
This control sets the baud rate to one of the following values:-

Baud Rate (bits per second)
75
110
134.5
150
300
600
1200
1800
2000
2400
4800
9600
19200

DATA BITS
This control sets the data transmission to one of four formats:-

Data Bits	Description
7 + 1 PARITY	7 data bits + 1 parity bit
8 + 1 PARITY	8 data bits + 1 parity bit
8 + NO PARITY	8 data bits + 0 parity bit
9 + NO PARITY	9 data bits + 0 parity bit

DELIMITER
The character shown is that sent by the model 7310 to separate two numeric values in a multi-value response, such as that generated by the DCT command. The corresponding ASCII value of this character is also shown, in brackets. For example, value 44 corresponds to a "," (comma).

RS232 ADDRESS
When more than one compatible instrument is connected in "daisy-chain" fashion by coupling the **AUX RS232** port on the rear panel of one to the **RS232** port on the next, this control is used to define the instrument's RS232 address. All daisy-chained

instruments receive commands but only the currently addressed instrument will implement or respond to them, except of course the command that changes the addressed instrument.

ECHO
This control, when switched on, causes the model 7310 to echo each character received over the RS232 interface back to the controlling computer. The computer should wait until the echoed character is returned until it sends the next character. When switched off, character echo is suppressed.

NOTE: Character echo should always be switched on, except when controlling the instrument from a simple RS232 terminal where operation without it might be possible.

PARITY
This control sets the parity check polarity when the Data Bits control specifies that a parity bit should be used. It should be set to match the setting of the controlling computer.

PROMPT
This control has two settings, as follows:-

PROMPT ON
A prompt character is generated by the model 7310 after each command response to indicate that the instrument is ready for a new command. The prompt character is either a "*" or a "?". If a "?" is generated, it indicates that an overload, reference unlock, parameter error or command error has occurred.

PROMPT OFF
No prompt character is generated.

Pressing a key adjacent to the Previous Menu item returns control to the Communications menu.

5.3.14 GPIB Comms Menu

When the Communications menu is displayed, pressing a key adjacent to the GPIB Comms item accesses the GPIB Comms menu, which is shown in figure 5-17.

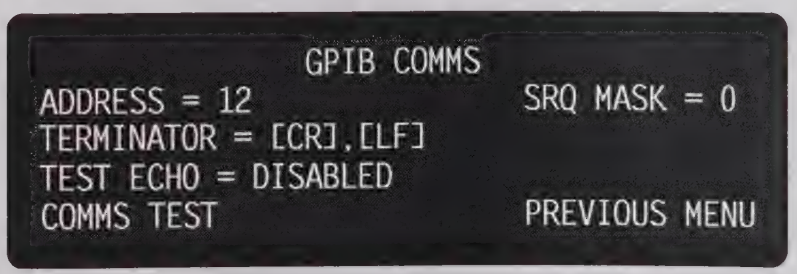


Figure 5-17, GPIB Comms Menu

This menu has four controls affecting the GPIB computer interface and a key for accessing the Comms Test menu, as follows:-

ADDRESS
This control sets the GPIB communications address to any value between 0 and 31. Each instrument used on the GPIB bus must have a unique address setting.

TERMINATOR
This has three possible settings, as follows:-

TERMINATOR = [CR],[LF]
A carriage return followed by a line feed are transmitted at the end of a response string, and in addition the GPIB interface line EOI (end of instruction) is asserted with the line feed character.

TERMINATOR = [EOI]
The GPIB interface line EOI (end of instruction) is asserted at the end of the response string. This gives the fastest possible operation since other termination characters are not needed.

TERMINATOR = [CR]
A carriage return is transmitted at the end of a response string, and in addition the GPIB interface line EOI (end of instruction) is asserted.

TEST ECHO
When this control is enabled, all transmissions to and from the instrument via the GPIB interface are echoed to the RS232 interface. Hence if a terminal is connected to the latter port, it will display any commands sent to the instrument and any responses generated, which can be useful during program development. When disabled, echoing does not occur. The control should always be disabled when not using this feature, since it slows down communications.

SRQ MASK
The instrument has the ability to generate a service request on the GPIB interface, to signal to the controlling computer that urgent attention is required. The request is generated when the result of a logical bit-wise AND operation between the Service Request Mask Byte, set by this control as a decimal value, and the instrument's Status Byte, is non-zero. The bit assignments for the Status Byte are as follows:-

Bit	Decimal Value	Status Byte
0	1	command complete
1	2	invalid command
2	4	command parameter error
3	8	Rear-panel DC OUTPUT overload
4	16	Signal Channel/DSP Output overload
5	32	new ADC values available after external trigger
6	64	asserted SRQ
7	128	data available

Hence, for example, if the SRQ mask byte is set to decimal 16 (i.e. bit 4 asserted), a

service request would be generated as soon as an overload occurred; if the SRQ mask byte were set to 0 (i.e. no bits asserted), then service requests would never be generated.

Pressing a key next to the Comms Test item accesses the Comms Test menu, and pressing a key adjacent to the Previous Menu item returns control to the Communications menu.

5.3.15 Comms Test Menu

When the Communications menu is displayed, pressing a key adjacent to the Comms Test item accesses the Comms Test menu, shown below in figure 5-18. It may also be accessed via the GPIB Comms menu.

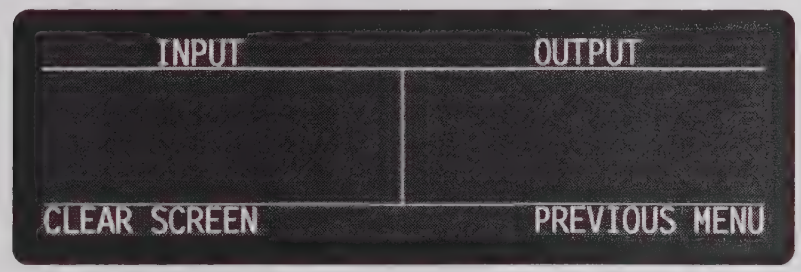


Figure 5-18, Comms Test Menu

This menu is useful when attempting to establish communications via the computer interfaces for the first time, or if a problem is suspected.

The Input side of the display shows all of the characters that have been received from the interface, whether valid or not. The Output side of the display shows all the characters that have been generated by the instrument and sent to the interface.

If characters received do not match those sent by the controlling computer then this indicates that an error has occurred either in the host computer or interface cable. If the interface cable is known to be good, then re-check either the GPIB or RS232 communications settings.

CLEAR SCREEN
The input and output displays scroll once they are full so that they always display the most recent characters received and sent. Pressing the Clear Screen key clears both areas.

NOTE: The Comms Test menu should not be displayed once communications problems have been resolved since it significantly slows down communications with the instrument. If the GPIB interface is used then this may cause GPIB timeout errors.

Pressing a key adjacent to the Previous Menu item returns control to either the Communications menu or the GPIB Comms menu, depending which menu was used to access the Comms Test menu.

5.3.16 '*' Command Options Menu

When the Communications menu is displayed, pressing a key adjacent to the '*' Command Options item accesses the '*' Command Options menu, shown in figure 5-19.

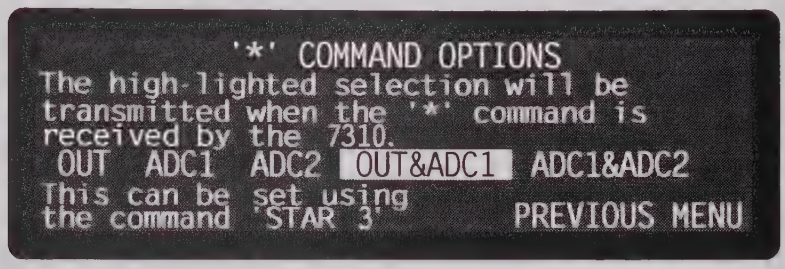

'*' COMMAND OPTIONS
The high-lighted selection will be transmitted when the '*' command is received by the 7310.
OUT ADC1 ADC2 OUT&ADC1 ADC1&ADC2
This can be set using the command 'STAR 3'
PREVIOUS MENU

Figure 5-19, '*' Command Options Menu

The star data transfer mode allows faster access to a subset of the instrument outputs, than is possible using the normal commands, to request the return of output values. The mode can be set up using either the computer command STAR [n], or via the '*' Command Options menu.

The menu shows five possible instrument outputs or pairs of outputs, one of which can be selected. This output will then be returned when the controlling computer sends an asterisk character (ASCII 42). The required output is selected using the adjacent (△)(▽) keys, and is indicated by being shown in reverse text.

Pressing a key adjacent to the Previous Menu item returns control to the Communications menu.

5.3.17 Digital Port Menu

When the Communications menu is displayed, pressing a key adjacent to the Digital Port item accesses the Digital Port menu, shown in figure 5-20.

Figure 5-20, Digital Port Menu

The Digital Port menu allows the status of each of the eight pins of the **DIGITAL OUTPUTS** connector on the rear panel to be set. Pinouts for this connector are given in appendix B. This port may be used for controlling external equipment, for example the switching of heaters or attenuators, via a suitable user-supplied external interface circuit.

The eight outputs are TTL compatible and are controlled by the digital output port byte, shown towards the upper right-hand side of the display as D7 - D0. Immediately under each of these bit-identifiers is a single character showing the current bit status, which is either a "0", in which case the output is at logic 0, (i.e. < 0.7 V), or a "1", in which case it is at logic 1, (i.e. > 2.4 V). The maximum current that each output line can source or sink is 2 mA.

The four [△][▽] keys on the left-hand side are used to toggle the bit-status of any bit, being treated for this purpose as eight single keys corresponding to the eight bit identifiers shown on the display. Each press of a given key toggles the state of the corresponding bit.

DECIMAL
This control provides an alternative way of changing the bit status. The number is the decimal equivalent of the displayed bit pattern, and consequently can be set to any number between 0 (all bits at logic "0") and 255 (all bits at logic "1").

Pressing a key adjacent to the Previous Menu item returns control to the Communications menu.

5.3.18 Buffer & Graphs Menu

When the Main Menu is displayed, pressing a key adjacent to the Buffer & Graphs item accesses the Buffer & Graphs menu, which is shown in figure 5-21.

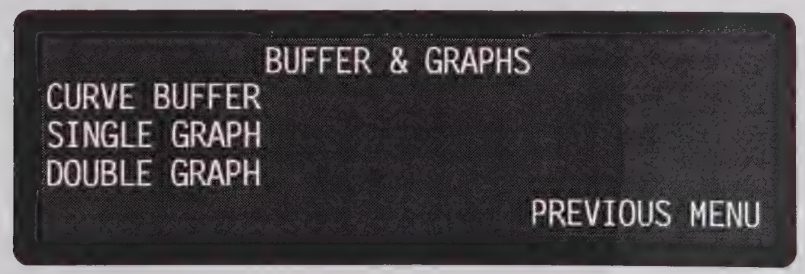


Figure 5-21, Buffer & Graphs Menu

The Buffer & Graphs menu has three keys used to access sub-menus, the relationship of which to the Main Menu is given in figure 5-22. Note that as with the main menu structure, shown in figure 5-1, it is possible to return to the Main Display from any menu by pressing the **MENU** key on the front panel, but this has been omitted from figure 5-22 for the sake of clarity.

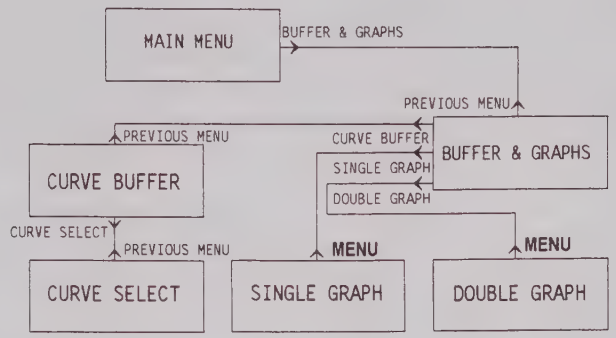


Figure 5-22, Buffer & Graphs Menu Structure

5.3.19 Curve Buffer Menu

When the Buffer & Graphs Menu is displayed, pressing a key adjacent to the Curve Buffer item accesses the Curve Buffer menu, which is shown in figure 5-23.

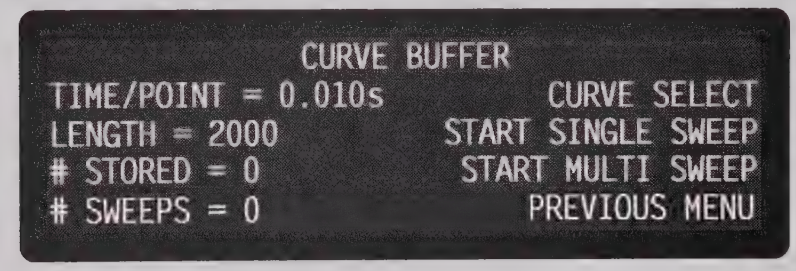


Figure 5-23, Curve Buffer Menu

The Curve Buffer menu has four controls affecting the instrument's internal 32768 point curve buffer, two status indicators and a key to access a further sub-menu, the Curve Select menu.

TIME/POINT
This control defines the interval between each data point (time per point) in the curve buffer. It may be set to values between 5 ms and 1 × 105 s and in addition, may also be set to 1.25 ms, at which setting only the main output is stored.

NOTE: If set to 1.25 ms then the curve selected for storage as shown in the Curve Select menu (see section 5.3.20) is automatically set to the OUTPUT data type when an acquisition is started by pressing either the Start Single Sweep or Start Multi Sweep keys.

In order to set the time per point, press a key adjacent to this item to display a pop-up keypad on the right-hand side of the display. Times are entered directly as required, except that if a time of zero seconds is specified, the control is actually set to 1.25 ms.

LENGTH
This control defines the number of points to be stored in the internal curve buffer when either single or repetitive sweeps are initiated. The buffer can hold a maximum of 32768 points, shared equally between the curve types as defined by the Curve Select menu (see section 5.3.20). Hence, for example, if 4 curve types are to be stored then the maximum curve length for each curve is 8192 points.

Note that if the number of curves to be stored is increased beyond that which may be stored at the current curve length, then the curve length is reduced automatically.

STORED
This shows the number of points stored in the curve buffer. The number is incremented at the rate defined by the time per point control. On completion of a sweep, in single-sweep mode, the number will be the same as the length control, whereas in multi-sweep mode the number increments continuously.

SWEEPS
This shows the number of completed sweeps, where one sweep is equal to the number of points specified by the length control setting. On completion of a sweep, in single-sweep mode, the number will be "1", whereas in multi-sweep mode the number increments continuously.

START SINGLE SWEEP
This key initiates a single sweep. If the length control is greater than 1 and a single sweep is in progress, then the controls change to Pause Single Sweep and Stop Single Sweep.

PAUSE SINGLE SWEEP
This key stops data acquisition at the current point, but acquisition may be restarted by pressing Cont. Single Sweep (Continue Single Sweep).

CONT. SINGLE SWEEP
This key restarts data acquisition from the current point.

STOP SINGLE SWEEP
This key stops data acquisition at the current point. Data already acquired remains in the curve buffer.

START MULTI SWEEP
This key initiates multiple sweeps. The controls change to Pause Multi Sweep and Stop Multi Sweep.

PAUSE MULTI SWEEP
This key stops data acquisition at the current point, but acquisition may be restarted by pressing Cont. Multi Sweep (Continue Multi-Sweep)

CONT. MULTI SWEEP
This key restarts data acquisition from the current point.

STOP MULTI SWEEP
This key stops data acquisition at the current point. Data already acquired remains in the curve buffer.

Pressing a key adjacent to the Previous Menu item returns control to the Buffer & Graphs menu.

5.3.20 Curve Select Menu

When the Curve Buffer menu is displayed, pressing a key adjacent to the Curve Select item accesses the Curve Select menu, which is shown in figure 5-24.

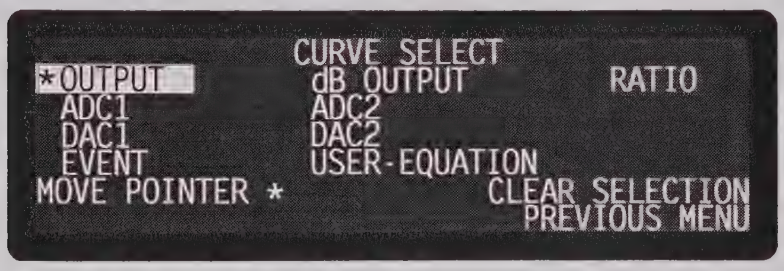


Figure 5-24, Curve Select Menu

The upper section of the Curve Select menu has a list of nine possible data types, that can be stored to the curve buffer, arranged in four rows of three columns. Two controls allow between one and nine of these data types to be selected for storage, with those that are selected being indicated by a tick mark and by being shown in reverse text.

MOVE POINTER *
This control allows the * pointer to be moved to any one of the possible data types.

ENTER SELECTION / CLEAR SELECTION
If the data type adjacent to the * pointer is not selected, then pressing this key causes it to be selected, as indicated by a tick mark adjacent to it and by its being displayed in reverse text. If it is already selected, then pressing the key deselects it.

NOTE: The data types selected for storage may be changed by controls on other menus, as follows:-

ADCs Menu (section 5.3.09)
Selecting any of the burst acquisition modes automatically selects the ADC1 or ADC1 and ADC2 outputs for storage.

Curve Buffer Menu (section 5.3.19)
Setting the Time/Point control to 1.25 ms and starting an acquisition by pressing either the Start Single Sweep or Start Multi Sweep keys automatically selects the OUTPUT output for storage.

Pressing a key adjacent to the Previous Menu item returns control to the Curve Buffer menu.

5.3.21 Single Graph Menu

When the Buffer & Graphs menu is displayed, pressing a key adjacent to the Single Graph item accesses the Single Graph menu, which is shown in figure 5-25.

Figure 5-25, Single Graph Menu

The Single Graph menu shows the contents of one curve stored in the curve buffer. This allows real-time or post-acquisition display of selected instrument outputs in "strip chart" format, and has a cursor for accurate determination of the output value at a given sample point.

If there is no data in the curve buffer then the graph will show a straight line representing zero. If curve storage is already running, or if there is data in the curve buffer, then a curve will be displayed with the most recent value at the right-hand side of the screen.

Figure 5-25 shows the layout of the single graph menu. The curve is displayed in the central section of the display, with the keys on either side being used to adjust the axes and to select the data to be shown, as follows:-

SCALE **keys**
The top and bottom left-hand (△)(▽) keys are used to adjust the upper and lower limits of the vertical axis, with the present maximum and minimum values being shown adjacent to them.

AUTO SCALE **keys**
The two middle pairs of left-hand (△)(▽) keys are used to auto-scale the upper and lower limits of the vertical axis to match the range present in the visible section of the displayed curve.

There is no facility for adjusting the x-axis scale, which always shows up to 156 points. Hence if a curve of more than this number of points is acquired it will not be possible to show all of the points on the display at the same time.

Curve Selection keys
The keys on the top right-hand side of the display are used to select the curve to be shown from those stored in the curve buffer. All curves that can be stored may be selected for display, except for the EVENT curve. For example, if only the OUTPUT and ADC1 curves were specified, using the Curve Select sub-menu, as being required then these would be the only two selections available.

LOOP/STOP and ONE SHOT/PAUSE/CONTINUE keys

In the single graph display mode, acquisition to the curve buffer, and hence display of data, can be initiated using the middle two right-hand △▽ keys. The upper pair start data acquisition in the loop mode, in which the curve buffer fills to capacity and is then sequentially overwritten by new data. Once this mode is running, the Loop control key annotation changes to Stop, and pressing an adjacent key will stop acquisition at the present data point.

The lower pair also start acquisition, but in the one-shot mode. This causes data to be acquired for the number of points specified by the curve length control in the Curve Buffer menu and once complete, acquisition ceases. During data acquisition, the control key annotation changes to Pause; if pressed again, acquisition will pause at the current data point and the annotation changes again to Cont. (Continue). If the key is pressed again acquisition continues from the present data point.

CURSOR keys

The bottom right-hand △▽ keys move the displayed cursor, which is only active when data is not being stored, from side to side. The present point number is shown in the bottom right-hand corner of the display and the value of the curve at its intersection with the cursor appears in the top right-hand corner. If the cursor is moved fully to the left then the displayed data scrolls to the right in groups of ten points, allowing earlier data to be shown.

If acquisition is in progress then the cursor is automatically positioned at the right-hand side of the display area and cannot be moved.

Pressing the **MENU** key on the front panel exits the Single Graph menu and returns to the Buffer & Graphs menu.

5.3.22 Double Graph Menu

When the Buffer & Graphs menu is displayed, pressing a key adjacent to the Double Graph item accesses the Double Graph menu, which is shown in figure 5-26.

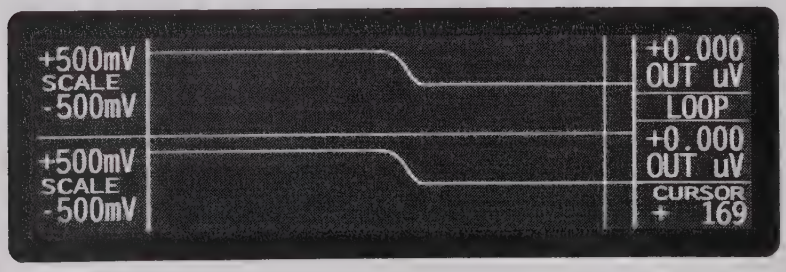


Figure 5-26, Double Graph Menu

The double graph display is similar to that of the single graph with the exception that one shot data acquisition cannot be initiated. If this mode of acquisition is required then it can be started from either the Single Graph or Curve Buffer menus prior to selecting Double Graph.

If there is no data in the curve buffer then the graph will show two horizontal straight lines representing zero. If curve storage is already running, or if there is data in the curve buffer, then two curves will be displayed with the most recent values at the right-hand side of the screen.

Figure 5-26 shows the layout of the double graph display. The two curves are displayed in the central section of the display, with the keys on either side being used to adjust the axes and to select the data to be shown, as follows:-

SCALE keys
The keys to the left-hand side of the display are used to set the upper and lower limits of the vertical axis, with the top and upper-middle (△)(▽) keys being used for the upper curve (Curve 1) and the lower-middle and bottom (△)(▽) keys for the lower curve (Curve 2). Pressing both sides of one of the key pairs simultaneously automatically sets the relevant limit to match the range present in the visible section of the displayed curve.

As in single graph mode, there is no facility for adjusting the x-axis scale, which always shows up to 156 points. Furthermore both the upper and lower curves are shown over the same range of points; it is not possible, for example, to show Curve 1 for data points 1 to 156 and Curve 2 for points 201 to 356.

Curve Selection keys
The keys on the top right-hand side of the display are used to select the curve to be shown in the upper half of the display, Curve 1, from those stored in the curve buffer. The lower-middle right-hand keys perform an equivalent function for Curve 2, which is shown in the lower half of the display. All curves that can be stored may be selected for display, except for the EVENT curve.

LOOP/STOP keys
In the double graph display mode only the loop method of data acquisition may be initiated. The upper-middle right-hand keys are used to start this mode, in which the curve buffer fills to capacity and is then sequentially overwritten by new data. During data acquisition, the Loop control key annotation changes to Stop, and pressing an adjacent key will then stop acquisition at the present data point.

CURSOR keys
As with the single graph mode, the bottom right-hand (△)(▽) keys control the position of the cursor. The current point number is displayed in the bottom right-hand corner of the display and the value of the curves at their intersection with the cursor appear above the relevant Curve 1 and Curve 2 data types. If the cursor is moved fully to the left then the displayed data scrolls to the right in groups of ten points, allowing earlier data to be shown.

Pressing the **MENU** key on the front panel exits the Double Graph menu and returns to the Buffer & Graphs menu.

This completes the description of the instrument's control and display menus.

5.4 Typical Noise-Rejecting Voltmeter Measurement

The model 7310 is a complex instrument with many controls and so readers may find the following basic checklist helpful in setting up the instrument for manual operation in a typical measurement.

Auto-Default
Use the Auto-Default function on the Auto Functions menu to set the instrument to a defined state.

Selection of Signal Input
Use the Signal Channel menu to select voltage (single-ended or differential) or current input mode, and connect the signal source to the relevant **A** and/or **B/I** input connector(s).

CAUTION: Remember that the impedance between the shell of the input connector and the instrument's chassis ground/power-cord ground connection is either 1 kΩ or nominally zero ohms, depending on the setting of the float control. Take care when connecting the input to the circuit under test to avoid introducing short circuits.

Filter Mode and Range
Set the filter mode to flat, and adjust the range control on the main display until the unit is displaying a signal level of up to 80 % of the full-scale sensitivity range, *subject to the condition that the instrument is not overloaded.*

Selection of Filter Mode and Settings
Use the Spectral Display to display the spectrum of the input signal and identify the frequency component to be measured. If this is larger than the background noise level then it will appear simply as a peak in the spectrum.

Set the filter mode to bandpass and use the frequency adjustment control to position the cursor directly under the peak. Next, adjust the bandwidth control so that the two cursors fully "bracket" the peak. Return to the Main Display.

As discussed in section 3.3.07, in bandpass mode it is important to set the filter frequency accurately, since any difference between it and the signal frequency can give rise to large errors, especially at high Q-factor settings.

The effect of the filter can be easily monitored visually by connecting the **SIGNAL MONITOR** and **FILTER OUTPUT** connectors on the rear panel to a dual-channel oscilloscope.

Auto-Range
Use the Auto-Range function on the Auto Functions menu to set the instrument so that it is correctly displaying the signal.

Other Adjustments
Use the controls on the Main Display to select the display required in the top and

bottom display positions. If a decibel ratio measurement is required then establish the zero dB level either by measuring the reference level and performing an Auto-Set 0dB operation or by manual entry.

If the analog **DC OUTPUT** of the instrument is to be used, then use the Output Channel menu to specify what the output signal should represent.

Computer Operation

Chapter 6

6.1 Introduction

The model 7310 includes both RS232 and GPIB (IEEE-488) interface ports, designed to allow the model 7310 to be completely controlled from a remote computer. All of the instrument's controls may be operated, and all the outputs read, via these interfaces.

This chapter describes the capabilities of the instrument when operated remotely and discusses how this is done.

6.2 Capabilities

All instrument controls that can be set using the front panel display menus, can also be set remotely. In addition, the present setting of each control may be determined by the computer. All instrument outputs that can be displayed on the front panel, can also be read remotely.

There are no commands to change which menu is displayed on the instrument, although if the Main Display menu is shown then the outputs allocated to the top and bottom right-hand positions can be selected.

6.3 RS232 and GPIB Operation

6.3.01 Introduction

Control of the model 7310 from a computer is accomplished by means of communications over the RS232 or GPIB interfaces. The communication activity consists of the computer sending commands to the instrument which responds, either by sending back some data or by changing the setting of one of its controls. The commands and responses are encoded in standard 7-bit ASCII format, with one or more additional bits as required by the interface (see below).

The two ports cannot be used simultaneously, but when a command has been completed, the instrument will accept a command at either port. Also when the test echo facility has been activated all output from the computer to the GPIB can be monitored by a terminal attached to the RS232 connector.

Although the interface is primarily intended to enable the instrument to be operated by a computer program specially written for an application, it can also be used in the direct, or terminal, mode. In this mode the user enters commands on a keyboard and reads the results on a monitor screen. In the default (power-up) state of the port, the instrument sends a convenient prompt character when it is ready to receive a

command, and echoes each character that is received.

The simplest way to establish the terminal mode is to connect a standard terminal, or a terminal emulator, to the RS232 port. A terminal emulator is a computer running special-purpose software that makes it act as a terminal.

Microsoft Windows versions 3.1 and 3.11 include a program called Terminal, and Windows 95 a program called Hyperterminal, usually in the Accessories group, which may be used as a terminal emulator. Alternatively, a simple terminal program with minimal facilities can be written in a few lines of BASIC code (see appendix C.1).

6.3.02 RS232 Interface - General Features

The RS232 interface in the model 7310 is implemented with three wires; one carries digital transmissions from the computer to the instrument, the second carries digital transmissions from the instrument to the computer and the third is the Logic Ground to which both signals are referred. The logic levels are ±12 V referred to Logic Ground, and the connection may be a standard RS232 cable in conjunction with a null-modem or alternatively may be made up from low-cost general purpose cable. The pinouts of the RS232 connectors are shown in appendix B and cable diagrams suitable for coupling the instrument to a computer are shown in appendix D.

The main advantages of the RS232 interface are:

1. It communicates via a serial port, which is present as standard equipment on nearly all computers, using leads and connectors which are available from suppliers of computer accessories or which can be constructed at minimal cost in the user's workshop.

2. It requires no more software support than is normally supplied with the computer, for example Microsoft's GWBASIC, QBASIC or Windows Terminal mode.

A single RS232 transmission consists of a start bit followed by 7 or 8 data bits, an optional parity bit and 1 stop bit. The rate of data transfer depends on the number of bits per second sent over the interface, usually called the baud rate. In the model 7310 the baud rate can be set to a range of different values up to 19,200, corresponding to a minimum time of less than 0.5 ms for a single character.

Mostly for historical reasons, there are a very large number of different ways in which RS232 communications can be implemented. Apart from the baud rate options, there are choices of data word length (7 or 8 bits), parity check operation (even, odd or none), and number of stop bits (1 or 2). With the exception of the number of stop bits, which is fixed at 1, these settings may be adjusted either by using the RS232 Comms menu, as discussed in chapter 5, or by means of the RS command.

NOTE: In order to achieve satisfactory operation, the RS232 settings must be set to exactly the same values in the terminal or computer as in the model 7310.

6.3.03 Choice of Baud Rate

Where the model 7310 is connected to a terminal, or to a computer, implementing an echo handshake, the highest available baud rate of 19,200 is normally used if, as is usually the case, this rate is supported by the terminal or computer. Lower baud rates may be used in order to achieve compatibility with older equipment or where there is some special reason for reducing the communication rate.

6.3.04 Choice of Number of Data Bits

The model 7310 uses the standard ASCII character set, containing 127 characters represented by 7-bit binary words. If an 8-bit data word is selected, the most significant bit is set to zero on output from the instrument and ignored on input. The result is that either the 8-bit or the 7-bit option may be used, but the 7-bit option can result in slightly faster communication.

6.3.05 Choice of Parity Check Option

Parity checks are not required at the baud rates available in the model 7310, that is up to 19,200 baud, with typical cable lengths of up to a few meters. Therefore no software is provided in the model 7310 for dealing with parity errors. Where long cables are in use, it may be advisable to make use of a lower baud rate. The result is that any of the parity check options may be used, but the no-parity option will result in slightly faster communication.

Where the RS232 parameters of the terminal or computer are capable of being set to any desired value, an arbitrary choice must be made. In the model 7310 the combination set at the factory is even parity check, 7 data bits, and one stop bit (fixed) because these are the MS-DOS defaults.

6.3.06 Auxiliary RS232 Interface

The auxiliary RS232 interface allows up to sixteen model 7310s, or a mixture of other compatible instruments, to be connected to one serial port on the computer. The first instrument is connected to the computer in the usual way. Additional instruments are then connected in a "daisy-chain" fashion using null-modem cables, the **AUX RS232** port of the first to the **RS232** port of the second, the **AUX RS232** port of the second to the **RS232** port of the third, etc. The address of each instrument is set up from the front panel before any communication takes place. At power-up the RS232 port of each instrument is fully active irrespective of its address. Since this means that all instruments in the daisy-chain are active on power-up, the first command must be \ n, where n is the address of one of them, which will deselect all but the addressed unit. When it is required to communicate with another instrument, send a new \ n command using the relevant address.

***NOTE: When programming in C remember that in order to send the character \ in a string it is necessary to type in ***

6.3.07 GPIB Interface - General Features

The GPIB is a parallel digital interface with 8 bi-directional data lines, and 8 further lines which implement additional control and communication functions. Communication is through 24-wire cables (including 8 ground connections) with special-purpose connectors constructed in such a way that they can be stacked on top of one another to enable numerous instruments to be connected in parallel. By means of internal hardware or software switches, each instrument is set to a different address on the bus corresponding to a number in the range 0 to 31. In the model 7310 the address is set either by using the GPIB Comms menu or by means of the GP command.

An important aspect of the GPIB is that its operation is defined in minute detail by the IEEE-488 standard, and is usually implemented by special-purpose semiconductor devices that are present in each instrument and which communicate with the instrument's microprocessor. The existence of this standard greatly simplifies the problem of programming the bus controller, i.e. the computer, to implement complex measurement and test systems involving the interaction of numerous instruments. There are fewer interface parameters to be set than with RS232 communications.

The operation of the GPIB requires the computer to be equipped with special-purpose hardware, usually in the form of a plug-in card, and associated software which enable it to act as a bus controller. The control program is written in a high-level language, usually BASIC or C, containing additional subroutines implemented by software supplied by the manufacturer of the interface card.

Because of the parallel nature of the GPIB and its very effective use of the control lines, including the implementation of a three-wire handshake (see below), comparatively high data rates, up to a few hundred thousand bytes per second, are possible. In a typical setup the data rate of the GPIB itself is not the factor that limits the rate of operation of the control program, but rather the speed with which the connected instruments can process and respond to commands.

6.3.08 Handshaking and Echoes

A handshake is a method of ensuring that the transmitter does not send a byte until the receiver is ready to accept it, and, in the case of a parallel interface, that the receiver reads the data lines only when they contain a valid byte.

GPIB Handshaking
The GPIB interface includes three lines (*DAV, *NRFD, *NDAC) which are used to implement a three-wire handshake. The operation of this is completely defined by the IEEE-488 standard and is fully automatic, so that the user does not need to know anything about the handshake when writing programs for the GPIB. Note that each command must be correctly terminated - see section 6.3.09.

RS232 Handshaking
In the RS232 standard there are several control lines called handshake lines (RTS, DTR outputs and CTS, DSR, DCD inputs) in addition to the data lines (TD output and RD input). However, these lines are not capable of implementing the handshaking

function required by the model 7310 on a byte-by-byte basis and are not connected in the model 7310 apart from the RTS and DTR outputs which are constantly asserted.

Note that some computer applications require one or more of the computer's RS232 handshake lines to be asserted. If this is the case, and if the requirement cannot be changed by the use of a software switch, the cable may be used in conjunction with a null-modem. A null-modem is an adapter which connects TD on each side through to RD on the other side, and asserts CTS, DSR, and DCD on each side when RTS and DTR are asserted on the opposite sides.

With most modern software there is no need to assert any RS232 handshake lines and a simple three-wire connection can be used. The actual handshake function is performed by means of bytes transmitted over the interface.

The more critical handshake is the one controlling the transfer of a command from the computer to the model 7310, because the computer typically operates much faster than the instrument and bytes can easily be lost if the command is sent from a program. (Note that because of the limited speed of human typing, there is no problem in the terminal mode.) Therefore an echo handshake is used, which works in the following way; after receiving each byte, the instrument sends back an echo, that is a byte which is a copy of the one that it has just received, to indicate that it is ready to receive the next byte. Correspondingly, the computer does not send the next byte until it has read the echo of the previous one. Usually the computer makes a comparison of each byte with its echo, and this constitutes a useful check on the validity of the communications.

Where the echo is not required, it can be suppressed by negating bit 3 in the RS232 parameter byte. The default (power-up) state of this bit is for it to be asserted.

The program RSCOM2.BAS in section C.2 illustrates the use of the echo handshake.

6.3.09 Terminators

In order for communications to be successfully established between the model 7310 and the computer, it is essential that each transmission, i.e. command or command response, is terminated in a way which is recognizable by the computer and the instrument as signifying the end of that transmission.

In the model 7310 there are three input termination options for GPIB communications, selectable either from the front panel under the GPIB Comms menu or by means of the GP command. The unit may be set to expect the <CR> byte (ASCII 13) or the <CR,LF> sequence (ASCII 13 followed by ASCII 10) to be appended by the controller as a terminator to the end of each command, or alternatively instead of a terminator it may expect the EOI signal line (pin 5 on the GPIB connector) to be asserted during the transmission of the last character of the command. The third option is normally to be preferred with modern interface cards which can easily be set to a wide variety of configurations.

The selected GPIB termination option applies also to the output termination of any responses sent back by the instrument to the controller, i.e. the model 7310 will send

<CR> or <CR,LF> or no byte as appropriate. In all cases the model 7310 asserts the EOI signal line during the transmission of the last byte of a response.

In RS232 communications, the instrument automatically accepts either <CR> or <CR,LF> as an input command terminator, and sends out <CR,LF> as an output response terminator, except when the noprompt bit (bit 4 in the RS232 parameter byte) is set in which case the terminator is <CR>. The default (power-up) state of this bit is zero.

6.3.10 Command Format

The simple commands listed in section 6.4 have one of six forms:

CMDNAME terminator
CMDNAME n terminator
CMDNAME [n] terminator
CMDNAME [n_1 [n_2]] terminator
CMDNAME n_1 [n_2] terminator
CMDNAME [n_1 n_2 n_3 n_4 n_5] terminator

where CMDNAME is an alphanumeric string that defines the command, and n, n_1, n_2, n_3, n_4 and n_5 are parameters separated by spaces. When n is not enclosed in square brackets it must be supplied. [n] means that n is optional. [n_1 [n_2]] means that n_1 is optional and if present may optionally be followed by n_2. Upper-case and lower-case characters are equivalent. Terminator bytes are defined in section 6.3.09.

Where the command syntax includes optional parameters and the command is sent without the optional parameters, the response consists of a transmission of the present values of the parameter(s).

Any response transmission consists of one or more numbers followed by a response terminator. Where the response consists of two or more numbers in succession, they are separated by a delimiter (section 6.3.11).

Depending on the command, n may be either an integer or a floating point value. The floating point output format (i.e. the format of floating point values returned by the instrument) is given below.

±1.234E±01

The number of digits between the decimal point and the exponent varies depending on the number but is a minimum of one and a maximum of eight. The input format is not as strict but if a decimal point is used there must be a digit before it. An exponent is optional. The following are all legal commands for setting the 0 dB level to 1 mV:-

ZERODB 0.001
ZERODB 1.000E-3
ZERODB +1E-3

6.3.11 Delimiters

Any response transmissions consist of one or two numbers followed by a response terminator. Where the response of the instrument consists of two numbers in succession, they are separated by a byte called a delimiter. This delimiter can be any printing ASCII character and is selected either via the RS232 Comms menu or by the use of the DD command.

6.3.12 Compound Commands

A compound command consists of two or more simple commands separated by semicolons (ASCII 59) and terminated by a single command terminator. If any of the responses involve data transmissions, each one is followed by an output terminator.

6.3.13 Status Byte, Prompts and Overload Byte

An important feature of the IEEE-488 standard is the serial poll operation by which a special byte, the status byte, may be read at any time from any instrument on the bus. This contains information which must be urgently conveyed from the instrument to the controller.

The function of the individual bits in the status byte is instrument dependent, apart from bit 6 (the request service bit) whose functions are defined by the standard.

In the model 7310, bits 0 and 7 signify "command complete" and "data available" respectively. In GPIB communications, the use of these bits can lead to a useful simplification of the control program by providing a response subroutine which is the same for all commands, whether or not they send a response over the bus. The principle is that after any command is sent, serial poll operations are repeatedly executed. After each operation bit 0 is tested; if this is found to be negated then bit 7 is tested, and if this is asserted then a read operation is performed. Serial poll operations continue until the instrument asserts bit 0 to indicate that the command-response sequence is complete. This method deals successfully with compound commands.

In RS232 communications, comparatively rapid access to the status byte is provided by the prompt character which is sent by the instrument at the same time as bit 0 becomes asserted in the status byte. This character is sent out by the instrument after each command response (whether or not the response includes a transmission over the interface) to indicate that the response is finished and the instrument is ready for a new command. The prompt takes one of two forms. If the command contained an error, either in syntax or by a command parameter being out of range, or alternatively if an overload or reference unlock is currently being reported by the front panel indicators, the prompt is ? (ASCII 63). Otherwise the prompt is * (ASCII 42).

These error conditions correspond to the assertion of bits 1, 2, 3 or 4 in the status byte. When the ? prompt is received by the computer, the ST command may be issued in order to discover which type of error exists and so that the appropriate action can be taken.

The prompts are a rapid way of checking on the status of the instrument and enable a convenient keyboard control system to be set up simply by attaching a standard terminal, or a simple computer-based terminal emulator, to the RS232 port. Where the prompt is not required it can be suppressed by setting the noprompt bit, bit 4 in the RS232 parameter byte. The default (power-up) state of this bit is zero.
A summary of the bit assignment in the status byte is given below.

Bit	Status Byte
bit 0	command complete
bit 1	invalid command
bit 2	command parameter error
bit 3	Rear-panel DC OUTPUT overload
bit 4	Signal Channel/DSP Output overload
bit 5	new ADC values available after external trigger
bit 6	asserted SRQ
bit 7	data available

6.3.14 Service Requests

The interface defined by the IEEE-488 standard includes a line (pin 10 on the connector) called the SRQ (service request) line which is used by the instrument to signal to the controller that urgent attention is required. At the same time that the instrument asserts the SRQ line, it also asserts bit 6 in the status byte. The controller responds by executing a serial poll of all the instruments on the bus and testing bit 6 of the status byte in order to discover which instrument was responsible for asserting the SRQ line. The status byte of that instrument is then further tested in order to discover the reason for the service request and to take appropriate action.

In the model 7310 the assertion of the SRQ line is under the control of a byte called the SRQ mask byte which can be set either by use of the MSK command or via the GPIB Comms menu. If any bit in the status byte becomes asserted, and the corresponding bit in the mask byte has a non-zero value, the SRQ line is automatically asserted. If the value of the mask byte is zero, the SRQ line is never asserted.

Hence, for example, if the SRQ mask byte is set to 16, a service request would be generated as soon as a signal channel or DSP overload occurred; if the SRQ mask byte were set to 0, then service requests would never be generated.

6.3.15 Comms Test Menu

A most useful feature of the model 7310 when troubleshooting communication problems is the Comms Test menu, which is described in detail in section 5.3.15. However, once the problem has been resolved it is recommended that the instrument be reset to Main Display mode to avoid slowing down communications.

6.4 Command Descriptions

This section lists the commands in logical groups, so that, for example, all commands associated with setting controls affecting the signal channel are shown together. Appendix E gives the same list of commands but in alphabetical order.

6.4.01 Signal Channel

IMODE [n] Current/Voltage mode input selector

The value of n sets the input mode according to the following table:

n	Input mode
0	Current mode off - voltage mode input enabled
1	Current mode enabled - connect signal to **B** input connector

If n = 0 then the input configuration is determined by the VMODE command.
If n = 1 then current mode is enabled irrespective of the VMODE setting.

VMODE [n] Voltage input configuration

The value of n sets up the input configuration according to the following table:

n	Input configuration
0	Both inputs grounded (test mode)
1	A input only
2	B input only
3	A-B differential mode

Note that the IMODE command takes precedence over the VMODE command.

FLOAT [n] Input connector shield float/ground control

The value of n sets the input connector shield switch according to the following table:

n	Selection
0	Ground
1	Float (connected to ground via a 1 kΩ resistor)

RANGE [n]
RANGE. Full-scale sensitivity control

The value of n sets the full-scale sensitivity according to the following table, depending on the setting of the IMODE control:

n	full-scale sensitivity	
	IMODE=0	IMODE=1
0	10 μV	10 pA
1	20 μV	20 pA
2	50 μV	50 pA
3	100 μV	100 pA
4	200 μV	200 pA
5	500 μV	500 pA

n	full-scale sensitivity	
	IMODE=0	IMODE=1
6	1 mV	1 nA
7	2 mV	2 nA
8	5 mV	5 nA
9	10 mV	10 nA
10	20 mV	20 nA
11	50 mV	50 nA
12	100 mV	100 nA
13	200 mV	200 nA
14	500 mV	500 nA
15	1 V	1 μA

The RANGE [n] command can be used to set and read the sensitivity, whilst the RANGE. command can only be used for reading it. The response to the RANGE. command is in volts or amps. For example, if IMODE = 0 and the sensitivity is 1 mV, the command RANGE would report 6 and the command RANGE. would report +1.0E-03. If IMODE was changed to 1, RANGE would still report 6 but RANGE. would report +1.0E-09

AR Perform an Auto-Range operation

The instrument adjusts its full-scale sensitivity so that the output lies between 30 % and 90 % of full-scale.

LF [n_1 n_2] Signal channel line frequency rejection filter control

The LF command sets the mode and frequency of the line frequency rejection (notch) filter according to the following tables:

n_1	Selection
0	Off
1	Enable 50 or 60 Hz notch filter
2	Enable 100 or 120 Hz notch filter
3	Enable both filters

n_2	Notch Filter Frequency
0	60 Hz (and/or 120 Hz)
1	50 Hz (and/or 100 Hz)

6.4.02 Digital Filter

FILT [n] Filter Mode Control

The FILT command sets the measurement mode of the digital filter according to the following table:

n	Filter Mode
0	Flat
1	Low-pass
2	Bandpass

FILTF [n] Filter Frequency Control

The FILTF [n] command sets the digital filter frequency according to the following paragraphs:

No filter mode (i.e. FILT 0)
The command has no effect, since the filter is not active.

Low-pass filter mode (i.e. FILT 1)
The parameter n sets the -3 dB cut-off frequency in hertz to any value between 10 Hz and 28 kHz, with a 1 Hz resolution.

Bandpass filter mode (i.e. FILT 2)
The parameter n sets the center frequency in hertz to any value between 1.000 Hz and 60 kHz, with a 1 mHz resolution, although the actual filter frequency control resolution is limited internally to about 1 part in 5000.

FILTQ [n] Bandpass Filter *Q*-Factor Control

The FILTQ [n] command sets the digital bandpass filter *Q*-factor to values between 2 and 100, according to the following table:

n	*Q*-factor
0	2
1	5
2	10
3	20
4	50
5	100

6.4.03 True RMS-DC Converter

ACRMS [n] Voltmeter Measurement Mode Control

The ACRMS command sets the measurement mode of the instrument according to the following table:

n	Selection
0	DC measurement mode
1	AC measurement mode

6.4.04 Signal Channel Output Smoothing

SLOPE [n] Output smoothing slope (roll-off) control

The value of n sets the slope of the output smoothing according to the following table:

n	Slope
0	6 dB/octave
1	12 dB/octave

TC [n]

TC. Output smoothing time constant control

The value of n sets the output smoothing time constant according to the following table:

n	output smoothing time constant
0	5 ms
1	10 ms
2	20 ms
3	50 ms
4	100 ms
5	200 ms
6	500 ms
7	1 s
8	2 s
9	5 s
10	10 s

The TC. command is only used for reading the output smoothing time constant, and reports the current setting in seconds. Hence if a TC 5 command were sent, TC would report 5 and TC. would report 2.0E-01, i.e. 0.2 s or 200 ms.

6.4.05 Signal Channel Output Amplifier

OF [n_1 [n_2]] Offset control

The value of n_1 sets the status of the offset facility according to the following table:

n_1	Selection
0	Disables offset
1	Enables offset facility

The range of n_2 depends on the measurement mode of the instrument, as follows:

DC measurement Mode

n_2 may be set to any value between 0 and ±100 %, in 0.01 % increments, of the present full-scale sensitivity range setting, and is specified in volts or amps, depending on the present input mode. For example, if the range is set to 500 mV, n_2 can range from -500E-3 to +500E-3 in steps of 5E-5.

AC measurement Mode

In voltage mode, n_2 may be set to any value between 0 and -1 V, in 1 nV increments, whilst in current mode, n_2 may be set to any value between 0 and -1 µA in 1 fA increments. In addition, the magnitude of the specified offset level must be less than the measured signal level with offset disabled.

AOF Auto-Offset

The output offset is turned on and set to a level giving zero output. Any changes in the input signal then appear as changes about zero in the output.

DCOUT [n] Analog output control

Defines which output appears on the **DC OUTPUT** connector on the rear panel according to the following table:

n	Signal
0	Output
1	dB Output
2	Ratio
3	Log Ratio
4	Equation

The relationship between the analog signal appearing at the connector and the front-panel display value, for each of the five possible settings, is given in section 5.3.06.

6.4.06 Instrument Outputs

OUT Output

The OUT command causes the instrument to respond with the output in volts or amps, depending on whether voltage or current input mode is selected, as follows.

Voltage Input Mode
The response lies in the range +0.0E00 (0 V) and +2.0E00 (2 V) (AC mode) or -2.0E00 (-2 V) and +2.0E00 (2 V) (DC mode)

Current Input Mode
The response lies in the range +0.0E00 (0 A) and +2.0E-06 (2 μA) (AC mode) or -2.0E-06 (-2 μA) and +2.0E-06 (2 μA) (DC mode)

ZERODB [n] Set 0 dB Level

The ZERODB command sets the 0 dB level which is used for calculation when the output mode is set to dB. The parameter n sets the level directly in volts or amps, depending on whether voltage or current input mode is selected, as follows:

Voltage Input Mode
The parameter n can be set to any value between 1E-9 (1 nV) and 1 (1 V)

Current Input Mode
The parameter n can be set to any value between 1E-15 (1 fA) and 1E-6 (1 μA)

AS Auto-Set 0dB

The AS command sets the present measured signal level as the 0 dB level which is used to calculate the dB output, and sets the Main Display to display this output type. Hence, for example, if the unit were displaying an output of 50 mV rms and the Auto-Set 0dB function were called, then the display would change to 0.000 dB. If the signal level then changed to 100 mV rms then this would appear as +6.02 dB in the dB display mode.

OUTDB dB Output

The OUTDB command causes the model 7310 to respond with the output expressed in decibels with respect to the preset zero dB level, as defined by the ZERODB command or set by the Auto-Set 0dB function. The response range is +12.0E1 (120 dB) to -6.0E1 (-60 dB)

RT Ratio output

The RT command reports a number equivalent to OUTPUT/ADC1 where OUTPUT is the value that would be returned by the OUT command and ADC1 is the value that would be returned by the ADC1 command.

LR Log Ratio output

The LR command reports a number equivalent to log(OUTPUT/ADC1), where OUTPUT is the value that would be returned by the OUT command and ADC1 is the value that would be returned by the ADC1 command. The response range is -3.000 to +2.079.

DEFEQU [n_1 n_2 n_3 n_4 n_5] Define user equation

The DEFEQU command is used to define the user equation, which takes the following form:

$$\text{Equation} = \left(\frac{(A \pm B) \times C}{D} \right)$$

The parameter n_2 is used to set the addition/subtraction operator in the numerator according to the following table:-

n_2	Operator
0	Subtraction
1	Addition

The parameters n_1, n_3, n_4 and n_5 specify the variables A, B, C and D respectively according to the following table:

n	Variable	Range
0	OUT	±30000
1	ADC1	±10000
2	ADC2	±10000
3	C1	0 to 99999
4	C2	0 to 99999
n	Variable	Range
5	0	zero
6	1	unity

C n_1 [n_2] User equation constants

The C n_1 [n_2] command is used to specify the values of the two constants, C1 and C2, used in the user equation. Parameter n_1 is used to select the constant, with $n_1 = 1$ corresponding to constant C1 and $n_1 = 2$ corresponding to constant C2. Parameter n_2 sets the value of the selected constant and can lie in the range 0 to 99999.

EQU Output result of user-specified equation

The value returned is the output of the user equation, where the equations are defined using the Equation Setup menus (see section 5.3.07) or via the DEFEQU command. The possible range is ±2,147,483,647 (signed 32-bit integer).

MAX Read Maximum Output

The MAX command returns the maximum output value, since the last reset operation. The response is in volts or amps, depending on whether voltage or current input mode is selected, as follows:

Voltage Input Mode
The response lies in the range +0.0E00 (0 V) and +2.0E00 (2 V) (AC mode) or -2.0E00 (-2 V) and +2.0E00 (2 V) (DC mode)

Current Input Mode
The response lies in the range +0.0E00 (0 A) and +2.0E-06 (2 μA) (AC mode) or -2.0E-06 (-2 μA) and +2.0E-06 (2 μA) (DC mode)

MIN Read Minimum Output

The MIN command returns the minimum output value, since the last reset operation. The response is in volts or amps, depending on whether voltage or current input mode is selected, as follows:

Voltage Input Mode
The response lies in the range +0.0E00 (0 V) and +2.0E00 (2 V) (AC mode) or -2.0E00 (-2 V) and +2.0E00 (2 V) (DC mode)

Current Input Mode
The response lies in the range +0.0E00 (0 A) and +2.0E-06 (2 μA) (AC mode) or -2.0E-06 (-2 μA) and +2.0E-06 (2 μA) (DC mode)

RESET Reset Maximum and Minimum Indicators

The RESET command duplicates the function provided by the **RESET** key on the front panel and the **RESET MAX/MIN** input on the rear panel, and resets the Maximum and Minimum output level indicators.

STAR [n] Star mode setup command

The star mode allows faster access to instrument outputs than is possible using the conventional commands. The mode is set up using the STAR command to specify the output(s) required and invoked by sending an asterisk (ASCII 42) to request the data. The data returned is specified by the value of n, as follows:

n	Data returned by * command
0	OUT
1	ADC1
2	ADC2
3	OUT & ADC1
4	ADC1 & ADC2

* Transfer command

This command establishes the high-speed transfer mode. Use the STAR command to set up the desired response to the * command, and then send an * (ASCII 42), without terminator, to the instrument. The instrument will reply with the selected output as quickly as possible, and then wait for another *. If the computer processes the reply quickly and responds immediately with another *, then very rapid controlled data transfer is possible.

The first transfer takes a little longer than subsequent ones because some overhead time is required for the model 7310 to get into the high-speed transfer mode. When in this mode, the front panel controls are inactive and the display is frozen.

The mode is terminated either by sending any command other than an *, when the instrument will exit the mode and process the new command, or after a period of 10 seconds following the last * command.

NOTE: Check that the computer program does not automatically add a carriage return or carriage return-line feed terminator to the * command, since these characters will slow down communications.

6.4.07 Auxiliary Outputs

DAC n_1 [n_2] Auxiliary DAC output controls

Sets the voltage appearing at the **DAC1, DAC2, DAC3** and **DAC4** outputs on the rear panel.

The first parameter n_1, which specifies the DAC, is compulsory and is either 1, 2, 3 or 4. The value of n_2 specifies the output voltage in volts, in the range -12.000 V to +12.000 V.

BYTE [n] Digital output port control

The value of n, in the range 0 to 255, determines the bits to be output to the digital output port on the rear panel. When n = 0, all outputs are low, and when n = 255, all are high.

6.4.08 Auxiliary Inputs

ADC n Read auxiliary analog to digital inputs

Reads the voltage appearing at the **ADC1** (n = 1) or **ADC2** (n = 2) inputs on the rear panel. The response for ADC1 and ADC2 is in volts.

TADC [n] Auxiliary ADC trigger mode control

The value of n sets the trigger mode of the auxiliary **ADC** inputs according to the following table:

n	Trigger mode
0	Asynchronous (5 ms intervals)
1	External (rear panel **TRIGGER** input)
2	Burst mode, fixed rate, triggered by command (ADC1 only)
3	Burst mode, fixed rate, triggered by command (ADC1 and ADC2)

n	Trigger mode
4	Burst mode, variable rate, triggered by command (ADC1 only)
5	Burst mode, variable rate, triggered by command (ADC1 and ADC2)
6	Burst mode, fixed rate, External trigger (rear panel **TRIGGER** input) (ADC1 only)
7	Burst mode, fixed rate, External trigger (rear panel **TRIGGER** input) (ADC1 and ADC2)
8	Burst mode, variable rate, External trigger (rear panel **TRIGGER** input) (ADC1 only)
9	Burst mode, variable rate, External trigger (rear panel **TRIGGER** input) (ADC1 and ADC2)

In the burst modes, data is stored in the curve buffer. Use the LEN command to set the number of points required. Note that it may be necessary to enter CBD 32 before setting the length, if the curve buffer has previously been used for more than one data type. The data is read out from the buffer using DCT 5 for ADC1 and DCT 6 for ADC2. If the length is set to more than 16384 and a burst mode which stores both ADC1 and ADC2 is specified then the curve length will automatically be reduced to 16384 points. Note also that setting the TADC parameter to any value other than 0 or 1 may affect the CBD parameter, as follows:

TADC parameter	Effect on CBD parameter
0	none
1	none
2	automatically set to 32
3	automatically set to 96
4	automatically set to 32
5	automatically set to 96
6	automatically set to 32
7	automatically set to 96
8	automatically set to 32
9	automatically set to 96

The maximum sampling rate depends on the number of ADC inputs used and whether the sampling is timed or simply runs as fast as possible. In the modes above described as Fixed Rate, sampling runs at the maximum possible rate, nominally 20 kHz, when sampling both ADC1 and ADC2 or 40 kHz when sampling ADC1 only. In the Variable Rate modes, the sampling speed is set by the BURSTRATE command.

BURSTRATE [n] Sets the burst mode sampling rate for ADC1 and ADC2

The parameter n sets the sample rate for the Variable Rate burst modes according to the following equations:

When storing only to ADC1:
(i.e. TADC 2, TADC 4, TADC 6 and TADC 8)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 157} \right) \text{Hz}$$

When storing to ADC1 and ADC 2:
(i.e. TADC 3, TADC 5, TADC 7 and TADC 9)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 1031} \right) \text{Hz}$$

For example when n = 20, the sample rate will be 24,353 Hz for ADC1.

6.4.09 Output Data Curve Buffer

CBD [n] Curve buffer define

Defines which data outputs are stored in the curve buffer when subsequent TD (take data), TDT (take data triggered) or TDC (take data continuously) commands are issued. Up to 8 curves, or outputs, may be acquired, as specified by the CBD parameter.

The CBD parameter is an integer between 1 and 2029, being the decimal equivalent of an 11-bit binary word. When a given bit is asserted, the corresponding output is selected for storage. When a bit is negated, the output is not stored. The bit function and range for each output are shown in the table below:

Bit	Decimal value	Output	Range
0	1	Output	see definition of OUT command
1	2	not used	
2	4	dB Output	see definition of OUTDB command
3	8	Ratio	
4	16	not used	
5	32	ADC1	±10.0 V
6	64	ADC2	±10.0 V
7	128	DAC1	±10.0 V
8	256	DAC2	±10.0 V
9	512	EVENT variable	0 to 32767
10	1024	User Equation	$\pm 2^{32}$

32768 points are available for data storage, shared equally between the specified curves. For example, if 8 outputs are stored then the maximum number of storage points would be 4096 (i.e. 32768/8). The LEN command sets the actual curve length, which cannot therefore be longer than 32768 divided by the number of curves selected. If more curves are requested than can be stored with the current buffer length, then the buffer length will be automatically reduced. Its actual length can of course be determined by sending the LEN command without a parameter.

LEN [n] Curve length control

The value of n sets the curve buffer length in effect for data acquisition. The maximum allowed value depends on the number of curves requested using the CBD command, and a parameter error results if the value given is too large. For this reason, if the number of points is to be increased and the number of curves to be stored is to be reduced using the CBD command, then the CBD command should be issued first.

NC New curve

Initializes the curve storage memory and status variables. All record of previously taken curves is removed.

STR [n] Storage interval control

Sets the time interval between successive points being acquired under the TD or TDC commands. n specifies the time interval in seconds with a resolution of 5 ms, input values being rounded up to a multiple of 5 ms. The longest interval that can be specified is 100,000 s corresponding to one point in about 27¾ hours.

In addition, n may be set to 0, which sets the time per point to 1.25 ms. However this only allows storage of the output. There is no need to issue a CBD 1 command to set this up since it happens automatically when acquisition starts.

TD Take data

Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until the buffer is full.

TDT n Take data triggered

Sets the instrument so that data acquisition will be initiated on receipt of a trigger at the **TRIGGER** connector on the rear panel. Two triggered modes are possible, as set by the value of n:

n	function
0	One complete curve is acquired for each trigger
1	One complete set of data points is acquired for each trigger. Note that in this mode the maximum trigger rate is 200 Hz and the storage interval control setting has no effect.

TDC Take data continuously

Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until halted by an HC command. The buffer is circular in the sense that when it has been filled, new data overwrites earlier points.

EVENT [n] Event marker control

During a curve acquisition, if bit 9 in the CBD command has been asserted, the instrument stores the value of the Event variable at each sample point. This can be used as a marker to indicate the point at which an experimental parameter was changed. The EVENT command is used to set this variable to any value between 0 and 32767.

HC Halt curve acquisition

Halts curve acquisition in progress. It is effective during both single (data acquisition initiated by TD or TDT command) and continuous (data acquisition initiated by TDC command) curve acquisitions. The curve may be restarted by means of the TD, TDT or TDC command, as appropriate.

M Curve acquisition status monitor

Causes the model 7310 to respond with four values that provide information concerning data acquisition, as follows:

First value, Curve Acquisition Status: a number with five possible values, defined by the following table:

First Value	Significance
0	No curve activity in progress.
1	Acquisition via TD or TDT command in progress and running.
2	Acquisition via TDC command in progress and running.
5	Acquisition via TD or TDT command in progress but halted by HC command.
6	Acquisition via TDC command in progress but halted by HC command.

Second value, Number of Sweeps Acquired: This number is incremented each time a TD or TDT is completed and each time a full cycle is completed on a TDC acquisition. It is zeroed by the NC command and also whenever a CBD or LEN command is applied without parameters.

Third value, Status Byte: The same as the response to the ST command. The number returned is the decimal equivalent of the status byte and refers to the previously applied command.

Fourth value, Number of Points Acquired: This number is incremented each time a point is taken. It is zeroed by the NC command and whenever CBD or LEN is applied without parameters.

DCT n Dump acquired curves to computer in table format

The DCT command is used to transfer data stored in the curve buffer to the controlling computer. The DCT parameter is an integer between 1 and 2029, being the decimal equivalent of an 11-bit binary number. When a given bit in the number is asserted, the corresponding curve is selected for transfer. When a bit is negated, the curve is not transferred. The bit corresponding to each curve is shown in the table below:

Bit	Decimal value	Curve	Range
0	1	Output	see definition of OUT command
1	2	not used	
2	4	dB Output	see definition of OUTDB command
3	8	Ratio	
4	16	not used	
5	32	ADC1	±10.0 V
6	64	ADC2	±10.0 V
7	128	DAC1	±10.0 V
8	256	DAC2	±10.0 V
9	512	EVENT variable	0 to 32767
10	1024	User Equation	$\pm 2^{32}$

The values of the selected curves at the same sample point are transferred as a group in the order of the above table, separated by the chosen delimiter character and terminated with the selected terminator. This continues until all the points have been transferred.

As an example, suppose CBD 33 had been sent, equivalent to asserting bits 0 and 5, then the Output and ADC1 values would be stored. The permitted values of n would therefore be 1, 32 and 33. DCT 1 and DCT 32 would transfer only one curve at a time, but DCT 33 would transfer the Output curve and the ADC1 curve simultaneously. A typical output data sequence would be:

<Output value$_1$><delim><ADC1 value$_1$><term>
<Output value$_2$><delim><ADC1 Value$_2$><term>
<Output value$_3$><delim><ADC1 Value$_3$><term>
<Output value$_4$><delim><ADC1 Value$_4$><term>
<Output value$_5$><delim><ADC1 Value$_5$><term>

etc., where <delim> and <term> are the delimiter and terminator characters respectively.

The computer program's subroutine which reads the responses to the DCT command needs to run a FOR...NEXT loop of length equal to the value set by the LEN (curve length) command, and must be able to separate the responses on each line for storage or processing.

Note that when using this command with the GPIB interface the serial poll must be used. After sending the DCT command, perform repeated serial polls until bit 7 is set, indicating that the instrument has an output waiting to be read. Then perform repeated reads in a loop, waiting each time until bit 7 is set, indicating that a new value is available. The loop should continue until bit 1 is set, indicating that the transfer is completed.

6.4.10 Computer Interfaces (RS232 and GPIB)

RS [n_1 [n_2]] Set/read RS232 interface parameters

The value of n_1 sets the baud rate of the RS232 interface according to the following table:

n_1	Baud rate (bits per second)
0	75
1	110
2	134.5
3	150
4	300
5	600
6	1200
7	1800
8	2000
9	2400
10	4800

n_1 Baud rate (bits per second)
11 9600
12 19200

The lowest five bits in n_2 control the other RS232 parameters according to the following table:

bit number	bit negated	bit asserted
0	data + parity = 8 bits	data + parity = 9 bits
1	no parity bit	1 parity bit
2	even parity	odd parity
3	echo disabled	echo enabled
4	prompt disabled	prompt enabled

GP [n_1 [n_2]] Set/Read GPIB parameters

n_1 sets the GPIB address in the range 0 to 31

n_2 sets the GPIB terminator and the test echo function according to the following table:

n	Terminator
0	[CR], test echo disabled
1	[CR], test echo enabled
2	[CR,LF], test echo disabled
3	[CR,LF], test echo enabled
4	no terminator, test echo disabled
5	no terminator, test echo enabled

In all cases the EOI line is asserted with the last byte of a response.

When the test echo is on, every character transmitted or received via the GPIB port is echoed to the RS232 port. This is provided solely as an aid to program development and should not be enabled during normal operation of the instrument.

\ n Address command

When the model 7310 is daisy-chained with other compatible instruments this command will change which instrument is addressed. All daisy-chained instruments receive commands but only the currently addressed instrument will implement or respond to the commands. The exception is the \ n command. If n matches the address set from the front panel the instrument will switch into addressed mode. If n does not match the address set from the front panel the instrument will switch into unaddressed mode. Note that the \ n command does not change the address of an instrument but which instrument is addressed.

NOTE: All instruments must have a unique address.

DD [n] Define delimiter control

The value of n, which can be set to 13 or from 32 to 125, determines the ASCII value of the character sent by the instrument to separate two numeric values in a multi-value response, such as that generated by the DCT command.

ST Report status byte

Causes the instrument to respond with the status byte, an integer between 0 and 255, which is the decimal equivalent of a binary number with the following bit-significance:

Bit Number	Significance
Bit 0	Command complete
Bit 1	Invalid command
Bit 2	Command parameter error
Bit 3	Rear-panel DC OUTPUT overload
Bit 4	Signal Channel/DSP Output overload
Bit 5	New ADC values available after external trigger
Bit 6	Asserted SRQ
Bit 7	Data available

NOTE: this command is not normally used in GPIB communications, where the status byte is accessed by performing a serial poll.

MSK [n] Set/read service request mask byte

The value of n sets the SRQ mask byte in the range 0 to 255.

REMOTE [n] Remote only (front panel lock-out) control

Allowed values of n are 0 and 1. When n is equal to 1, the instrument enters remote only mode in which the front panel control functions are inoperative and the instrument can only be controlled with the RS232 or the GPIB interfaces. When n is equal to 0, the front panel controls function normally.

6.4.11 Instrument Identification

ID Identification

Causes the instrument to respond with the number 7310.

REV Report firmware revision

Causes the instrument to respond with the firmware revision number. This gives a four line response which the controlling program must be able to accept.

VER Report firmware version

Causes the instrument to respond with the firmware version number. The firmware version number is the number displayed on the front panel LCD Settings menu.

6.4.12 Front Panel

DISP n Display Mode Control

The DISP n command is used to set the display to two of the three possible display modes, as follows:

n	Display
0	Main Display
1	Large Digits Display

DISPOUT n_1 [n_2] Main Display Output Selector

This command is used to specify which outputs are displayed on the Main Display. Parameter n_1 specifies the display to be modified and is either 0 or 1, corresponding to the top and bottom display positions on the right-hand side. Parameter n_2 is used to choose which output appears in the chosen position, in accordance with the following table:-

Top Display Position (n_1 = 0), always a digital meter.
Note that this also sets the output which appears in the Large Digits display.

n_2	Displayed Output
0	ADC1
1	ADC2
2	Output
3	dB Output

Bottom Display Position (n_1 = 1).

n_2	Displayed Output and Type
0	ADC1, center zero bar-graph
1	ADC2, center zero bar-graph
2	Output, bar-graph
3	ADC1, small digital display
4	ADC2, small digital display
5	Output, small digital display

LTS [n] Lights on/off control

The value of n controls the front panel LEDs and LCD backlight according to the following table:

n	Selection
0	All lights off
1	Normal operation

6.4.13 Auto Default

ADF n Auto-Default command

This command will automatically set all the instrument controls and displays to the predefined states. The value of n is used to define which controls are affected, according to the following table:

n	Effect
0	Complete reset to factory-set default values (listed in appendix F)
1	Reset to factory-set default values (listed in appendix F), with the exception of the RS232 and GPIB communications interface settings, and the LCD display contrast setting.

NOTE: If the ADF 0 command is used when the interface parameters are at values other than their default settings, then communication will be lost.

6.5 Programming Examples

6.5.01 Introduction

This section gives some examples of the commands that need to be sent to the model 7310 for typical measurement situations.

6.5.02 Basic Signal Measurement

In a typical simple measurement, the computer is used to set the instrument controls and then to record the chosen outputs, perhaps as a function of time. At sampling rates of up to a few points per second, there is no need to use the internal curve buffer. The commands to achieve this would therefore be similar to the following sequence:

VMODE 1	Single-ended voltage input mode
LF 0	Turn off line frequency rejection filter
ACRMS 1	Set to AC measurement mode
FILT 2	Set to bandpass filter
FILTF 10E3	Set bandpass filter frequency to 10 kHz
FILTQ 3	Set bandpass filter *Q*-factor to 20
AR	Auto-Range
TC 3	Set output smoothing time constant to 50 ms

Then the output could be read as follows:

OUT	Reads output in volts

The controlling program would send a new output command each time a new reading were required. Note that a good "rule of thumb" is to wait for a period of four time constants (at a slope of 12 dB/octave) after the input signal has changed before recording a new value. Hence in a scanning type measurement, the program should issue the commands to whatever equipment causes the input signal to the model 7310 to change, wait for five time constants, and then record the required output.

6.5.03 Output Curve Storage Measurement

In this example, the instrument is measuring a current input signal applied to the **B** input connector and the measured output and the voltage at the **ADC1** input connector are recorded for 10 seconds at a 100 Hz sampling rate. The acquired curves as read back to the computer are required in floating point mode.

The sequence of commands is therefore as follows:

IMODE 1	High bandwidth current input mode
LF 0	Turn off line frequency rejection filter
RANGE 6	Set sensitivity to 1 nA full-scale
TC 3	Set time constant to 50 ms
ACRMS 1	Set to AC measurement mode

FILT 2	Set to bandpass filter
FILTF 1E3	Set bandpass filter frequency to 1 kHz
FILTQ 2	Set bandpass filter Q-factor to 10

Now the curve storage needs to be set up:

NC	Clear and reset curve buffer
CBD 33	Stores the Output and ADC1 values (i.e. bits 0 and 5)
LEN 1000	Number of points = 100 Hz × 10 seconds
STR 10E-3	Store a point every 10 ms (1/100 Hz)

The data is acquired by issuing:

TD	Acquires data

As the acquisition is running, the M command reports the status of the curve acquisition. Once this indicates the acquisition is complete (i.e. parameter 1 = 0, parameter 2 = 1), the acquired data may be transferred to the computer using:

DCT 0	Transfers Output values in amps.
DCT 32	Transfers ADC1 values in volts.

The input routine of the program must be prepared to read and store 1000 responses to each of these commands.

6.5.04 Transient Recorder

In this example, the noise-rejecting capabilities of the instrument are not used, but the auxiliary inputs are. The voltage applied to the **ADC1** input on the rear panel is sampled and digitized at a rate of approximately 40 kHz, with the values being stored to the curve buffer. Sampling is required to start on receipt of a trigger at the **TRIGGER** connector on the rear panel and must last for 500 ms.

The sequence of commands is therefore as follows:

NC	Clear and reset curve buffer
LEN 20000	500 ms recording time at 40 kHz = 20,000 points
TADC 6	Set ADC1 sampling to burst mode, fixed rate (40 kHz), external trigger, and arm trigger

As soon as a trigger occurs, the acquisition starts. Once it completes the acquired data may be transferred to the computer using:-

DCT 5	Transfers ADC1 values in volts

The input routine of the program must be prepared to read and store 20,000 responses to this command.

Specifications

Appendix A

Measurement Modes

AC RMS voltage or current
AC RMS voltage or current with respect to preset 0dB level
Average DC voltage or current
Average DC voltage or current with respect to preset 0dB level
Minimum signal since last reset operation
Maximum signal since last reset operation

Displays

Cold fluorescent backlit 64 × 240 pixel dot-matrix LCD with the following displays:-

Main Display
Principal instrument controls and digital and analog bar-graph displays of measured signals.

Spectral Display
Spectral density of input signal over selected frequency range with a linear or logarithmic power scale.

Large Digits Display
One selected instrument output shown in large digital format.

Graphical Display
Display of one or two selected instrument outputs, or auxiliary inputs, as a function of time.

Other Menus
Menu system with dynamic key function allocation allowing access to all instrument controls. On-screen context sensitive help.

Signal Channel

Voltage Inputs

Modes	A only, B only or Differential (A-B)
Full-scale Sensitivity Range	
AC measurement mode	10 μV to 1 V rms in a 1-2-5 sequence
DC measurement mode	1 mV to 1 V in a 1-2-5 sequence
Input Impedance	10 MΩ // 30 pF
Maximum Safe Input	30 V pk-pk
Voltage Noise	5 nV/√Hz at 1 kHz
C.M.R.R.	> 100 dB at 1 kHz degrading by 6 dB/octave

Frequency Response	
AC measurement mode	300 mHz to 60 kHz
Gain Accuracy	0.2 % typ, 0.6 % max. (full bandwidth)
Distortion	-90 dB THD (60 dB signal channel gain, 1 kHz)
Grounding	BNC shields can be grounded or floated via 1 kΩ to ground

Current Input

Full-scale Sensitivity	10 pA to 1 μA in a 1-2-5 sequence
Frequency Response	
AC measurement mode	300 mHz to 50 kHz
Input Impedance	< 250 Ω at 1 kHz
Maximum Safe Input	30 V pk-pk
Noise	130 fA/√Hz at 1 kHz
Gain Accuracy (midband)	≤ 0.6 % typ
Grounding	BNC shields can be grounded or floated via 1 kΩ to ground

Line Filter

Type	Two cascaded, analog, second-order, frequency rejection (notch) stages, set to center frequencies equal to the line frequency (F) and twice the line frequency respectively.
Settings	F, 2F, F&2F or disabled
Frequency Rejection	Each stage gives greater than 34 dB attenuation at ±2 % of center frequency.

Main ADC

Type	18-bit ADC
Sampling Rate	200 kHz

Digital Filter

Type	Two cascaded, second-order, digital filter stages giving an overall fourth-order response.
Settings	Bandpass, Low-pass or Flat
Controls	
Bandpass	
Center Frequency	1.000 Hz to 60 kHz
Q-factor	2 to 100 in a 1-2-5 sequence
Low-pass	
-3 dB Frequency	10 Hz to 28 kHz
Flat	None

True RMS-DC Converter & Output Processor

Description	True rms algorithm implemented using a DSP running at a 200 kHz sampling rate and managed by a powerful 68000-series host processor
Output Zero Stability	
Digital Outputs	No zero drift on all settings
Displays	No zero drift on all settings
Analog Outputs	< 5 ppm/°C
Output Smoothing	
Time Constant	5 ms to 10 s in a 1-2-5 sequence
Slope	6 or 12 dB/octave
Offset	Auto and Manual offset of up to ±100 % of the full-scale sensitivity range applied prior to the RMS-DC conversion.

Auxiliary Inputs

ADC 1 and 2	
Maximum Input	±10 V
Resolution	1 mV
Accuracy	±25 mV at full-scale
Input Impedance	1 MΩ // 30 pF
Sample Rate	
ADC 1 only	40 kHz max.
ADC 1 and 2	13 kHz max.
Trigger Mode	Internal, External or burst
Trigger input	TTL compatible

Outputs

Signal Monitor	
Amplitude	±10 V FS
Impedance	1 kΩ
Filter Output	
Function	Representation of input signal after filtering by digital filter stage
Amplitude	±10 V (100 % = ±5.0 V in bandpass mode)
Update Rate	200 kHz
Output Bandwidth	25 kHz
Output Impedance	1 kΩ

FILT 2	Set to bandpass filter
FILTF 1E3	Set bandpass filter frequency to 1 kHz
FILTQ 2	Set bandpass filter *Q*-factor to 10

Now the curve storage needs to be set up:

NC	Clear and reset curve buffer
CBD 33	Stores the Output and ADC1 values (i.e. bits 0 and 5)
LEN 1000	Number of points = 100 Hz × 10 seconds
STR 10E-3	Store a point every 10 ms (1/100 Hz)

The data is acquired by issuing:

TD	Acquires data

As the acquisition is running, the M command reports the status of the curve acquisition. Once this indicates the acquisition is complete (i.e. parameter 1 = 0, parameter 2 = 1), the acquired data may be transferred to the computer using:

DCT 0	Transfers Output values in amps.
DCT 32	Transfers ADC1 values in volts.

The input routine of the program must be prepared to read and store 1000 responses to each of these commands.

6.5.04 Transient Recorder

In this example, the noise-rejecting capabilities of the instrument are not used, but the auxiliary inputs are. The voltage applied to the **ADC1** input on the rear panel is sampled and digitized at a rate of approximately 40 kHz, with the values being stored to the curve buffer. Sampling is required to start on receipt of a trigger at the **TRIGGER** connector on the rear panel and must last for 500 ms.

The sequence of commands is therefore as follows:

NC	Clear and reset curve buffer
LEN 20000	500 ms recording time at 40 kHz = 20,000 points
TADC 6	Set ADC1 sampling to burst mode, fixed rate (40 kHz), external trigger, and arm trigger

As soon as a trigger occurs, the acquisition starts. Once it completes the acquired data may be transferred to the computer using:-

DCT 5	Transfers ADC1 values in volts

The input routine of the program must be prepared to read and store 20,000 responses to this command.

Specifications

Appendix A

Measurement Modes

AC RMS voltage or current
AC RMS voltage or current with respect to preset 0dB level
Average DC voltage or current
Average DC voltage or current with respect to preset 0dB level
Minimum signal since last reset operation
Maximum signal since last reset operation

Displays

Cold fluorescent backlit 64 × 240 pixel dot-matrix LCD with the following displays:-

Main Display
Principal instrument controls and digital and analog bar-graph displays of measured signals.

Spectral Display
Spectral density of input signal over selected frequency range with a linear or logarithmic power scale.

Large Digits Display
One selected instrument output shown in large digital format.

Graphical Display
Display of one or two selected instrument outputs, or auxiliary inputs, as a function of time.

Other Menus
Menu system with dynamic key function allocation allowing access to all instrument controls. On-screen context sensitive help.

Signal Channel

Voltage Inputs

Modes	A only, B only or Differential (A-B)
Full-scale Sensitivity Range	
AC measurement mode	10 μV to 1 V rms in a 1-2-5 sequence
DC measurement mode	1 mV to 1 V in a 1-2-5 sequence
Input Impedance	10 MΩ // 30 pF
Maximum Safe Input	30 V pk-pk
Voltage Noise	5 nV/√Hz at 1 kHz
C.M.R.R.	> 100 dB at 1 kHz degrading by 6 dB/octave

Frequency Response	
AC measurement mode	300 mHz to 60 kHz
Gain Accuracy	0.2 % typ, 0.6 % max. (full bandwidth)
Distortion	-90 dB THD (60 dB signal channel gain, 1 kHz)
Grounding	BNC shields can be grounded or floated via 1 kΩ to ground

Current Input

Full-scale Sensitivity	10 pA to 1 μA in a 1-2-5 sequence
Frequency Response	
AC measurement mode	300 mHz to 50 kHz
Input Impedance	< 250 Ω at 1 kHz
Maximum Safe Input	30 V pk-pk
Noise	130 fA/√Hz at 1 kHz
Gain Accuracy (midband)	≤ 0.6 % typ
Grounding	BNC shields can be grounded or floated via 1 kΩ to ground

Line Filter

Type	Two cascaded, analog, second-order, frequency rejection (notch) stages, set to center frequencies equal to the line frequency (F) and twice the line frequency respectively.
Settings	F, 2F, F&2F or disabled
Frequency Rejection	Each stage gives greater than 34 dB attenuation at ±2 % of center frequency.

Main ADC

Type	18-bit ADC
Sampling Rate	200 kHz

Digital Filter

Type	Two cascaded, second-order, digital filter stages giving an overall fourth-order response.
Settings	Bandpass, Low-pass or Flat
Controls	
Bandpass	
Center Frequency	1.000 Hz to 60 kHz
Q-factor	2 to 100 in a 1-2-5 sequence
Low-pass	
-3 dB Frequency	10 Hz to 28 kHz
Flat	None

True RMS-DC Converter & Output Processor

Description	True rms algorithm implemented using a DSP running at a 200 kHz sampling rate and managed by a powerful 68000-series host processor
Output Zero Stability	
Digital Outputs	No zero drift on all settings
Displays	No zero drift on all settings
Analog Outputs	< 5 ppm/°C
Output Smoothing	
Time Constant	5 ms to 10 s in a 1-2-5 sequence
Slope	6 or 12 dB/octave
Offset	Auto and Manual offset of up to ±100 % of the full-scale sensitivity range applied prior to the RMS-DC conversion.

Auxiliary Inputs

ADC 1 and 2	
Maximum Input	±10 V
Resolution	1 mV
Accuracy	±25 mV at full-scale
Input Impedance	1 MΩ // 30 pF
Sample Rate	
ADC 1 only	40 kHz max.
ADC 1 and 2	13 kHz max.
Trigger Mode	Internal, External or burst
Trigger input	TTL compatible

Outputs

Signal Monitor	
Amplitude	±10 V FS
Impedance	1 kΩ
Filter Output	
Function	Representation of input signal after filtering by digital filter stage
Amplitude	±10 V (100 % = ±5.0 V in bandpass mode)
Update Rate	200 kHz
Output Bandwidth	25 kHz
Output Impedance	1 kΩ

DC Output

Function	OUTPUT, dB OUTPUT, RATIO, LOG RATIO or USER EQUATION.
Amplitude	±10 V full-scale
Impedance	1 kΩ
Update Rate	200 Hz

Auxiliary DAC Output 1, 2, 3 & 4

Maximum Output	±10 V
Resolution	1 mV
Output Impedance	1 kΩ

8-bit Digital Output — 8 TTL-compatible lines that can be independently set high or low to activate external equipment

Power - Low Voltage — ±15 V at 100 mA rear panel DIN connector for powering EG&G preamplifiers

Data Storage

Data Buffer

Size	32k 16-bit and 32-bit data points, may be organized as 1×32k, 2×16k, 3×10.6k, 4×8k, etc.
Max Storage Rate	
From NRV	up to 800 16-bit values per second
From ADC1	up to 40,000 16-bit values per second

Interfaces

RS232, GPIB (IEEE-488). A second RS232 port is provided to allow "daisy-chain" connection and control of up to 16 units from a single RS232 computer port.

General

Power Requirements

Voltage	110/120/220/240 VAC
Frequency	50/60 Hz
Power	< 40 VA

Dimensions

Width	350 mm (13.75 ")
Depth	415 mm (16.5 ")
Height	
With feet	105 mm (4.1 ")
Without feet	91 mm (3.6 ")

Weight — 8.1 kg (18 lb)

All specifications subject to change without notification

Pinouts

Appendix B

B.1 RS232 Connector Pinout

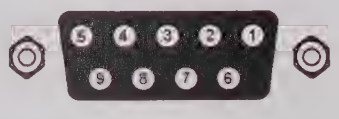


Figure B-1, RS232 and AUX RS232 Connector (Female)

Pin	Function	Description
2	RXD	Data In
3	TXD	Data Out
5	GND	Signal Ground
7	RTS	Request to Send - Always +12 V

All other pins are not connected

B.2 Preamplifier Power Connector Pinout

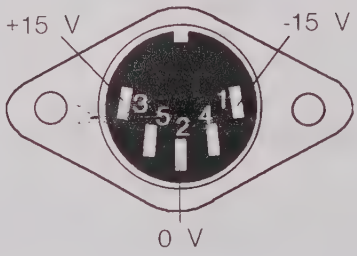


Figure B-2, Preamplifier Power Connector

Pin	Function
1	-15 V
2	Ground
3	+15 V

Pins 4 and 5 are not connected. Shell is shield ground.

B.3 Digital Output Port Connector

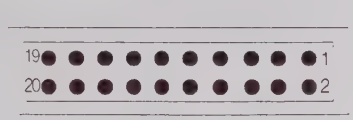


Figure B-3, Digital Output Port Connector

8-bit TTL-compatible output set from the front panel or via the computer interfaces. Each line can drive 3 LSTTL loads. The connector will mate with a 20-pin IDC header plug (not supplied). The pinout is as follows:-

Pin	Function
1	Ground
2	Ground
3	D0
4	Ground
5	D1
6	Ground
7	D2
8	Ground
9	D3
10	Ground
11	D4
12	Ground
13	D5
14	Ground
15	D6
16	Ground
17	D7
18	Ground
19	D8
20	Ground

D0 = Least Significant Bit
D7 = Most Significant Bit

Demonstration Programs

Appendix C

C.1 Simple Terminal Emulator

This is a short terminal emulator with minimal facilities, which will run on a PC-compatible computer in a Microsoft GWBASIC or QuickBASIC environment, or can be compiled with a suitable compiler.

```
10 'MINITERM 9-Feb-96
20 CLS : PRINT "Noise rejecting voltmeter RS232 parameters must be set to 9600 baud,
   7 DATA bits, 1 stop bit and even parity"
30 PRINT "Hit <ESC> key to exit"
40 OPEN "COM1:9600,E,7,1,CS,DS" FOR RANDOM AS #1
50 '.............................
60 ON ERROR GOTO 180
70 '.............................
100 WHILE (1)
110     B$ = INKEY$
120     IF B$ = CHR$(27) THEN CLOSE #1: ON ERROR GOTO 0: END
130     IF B$ <> "" THEN PRINT #1, B$;
140     LL% = LOC(1)
150     IF LL% > 0 THEN A$ = INPUT$(LL%, #1): PRINT A$;
160 WEND
170 '.............................
180 PRINT "ERROR NO."; ERR: RESUME
```

C.2 RS232 Control Program with Handshakes

RSCOM2.BAS is a user interface program which illustrates the principles of the echo handshake. The program will run on a PC-compatible computer either in a Microsoft GWBASIC or QuickBASIC environment, or in compiled form.

The subroutines in RSCOM2 are recommended for incorporation in the user's own programs.

```
10 'RSCOM2 9-Feb-96
20 CLS : PRINT " Noise rejecting voltmeter RS232 parameters must be set to 9600 baud,
   7 data bits, 1 stop bit, even parity"
30 OPEN "COM1:9600,E,7,1,CS,DS" FOR RANDOM AS #1
40 CR$ = CHR$(13)                                   ' carriage return
50 '
60 '...main loop.................
70 WHILE 1                                          ' infinite loop
80     INPUT "command (00 to exit) "; B$            ' no commas are allowed in B$
90     IF B$ = "00" THEN END
100    B$ = B$ + CR$                                ' append a carriage return
```

```
110     GOSUB 180                                   ' output the command B$
120     GOSUB 310: PRINT Z$;                        ' read and display response
130     IF A$ = "?" THEN GOSUB 410: GOSUB 470       ' if "?" prompt fetch STATUS%
140                                                 ' and display message
150 WEND                                            ' return to start of loop
160 '
170 '
180 '...output the string B$.............
190 ON ERROR GOTO 510                               ' enable error trapping
200 IF LOC(1) > 0 THEN A$ = INPUT$(LOC(1), #1)      ' clear input buffer
210 ON ERROR GOTO 0                                 ' disable error trapping
220 FOR J1% = 1 TO LEN(B$)                          ' LEN(B$) is number of bytes .
230     C$ = MID$(B$, J1%, 1): PRINT #1, C$;        ' send byte
240     WHILE LOC(1) = 0: WEND                      ' wait for byte in input buffer
250     A$ = INPUT$(1, #1)                          ' read input buffer
260     IF A$ <> C$ THEN PRINT "handshake error"    ' input byte should be echo
270 NEXT J1%                                        ' next byte to be sent or
280 RETURN                                          ' return if no more bytes
290 '
300 '
310 '....read response..................
320 A$ = "": Z$ = ""
330 WHILE (A$ <> "*" AND A$ <> "?")                 ' read until prompt received
340     Z$ = Z$ + A$                                ' append next byte to string
350     WHILE LOC(1) = 0: WEND                      ' wait for byte in input buffer
360     A$ = INPUT$(1, #1)                          ' read byte from buffer
370 WEND                                            ' next byte to be read
380 RETURN                                          ' return if it is a prompt
390 '
400 '
410 '....fetch status byte..............
420 B$ = "ST" + CR$                                 ' "ST" is the status command
430 GOSUB 180                                       ' output the command
440 GOSUB 310                                       ' read response into Z$
450 STATUS% = VAL(Z$)                               ' convert to integer
460 RETURN
470 '....instrument error message.......
480 PRINT "Error prompt, status byte = "; STATUS% ' bits are defined in manual
490 PRINT
500 RETURN
510 '....I/O error routine..............
520 RESUME
```

C.3 GPIB User Interface Program

GPCOM.BAS is a user interface program which illustrates the principles of the use of the serial poll status byte to coordinate the command and data transfer.

The program runs under Microsoft GWBASIC or QuickBASIC on a PC-compatible computer fitted with a National Instruments IEEE-488 interface card and with the GPIB.COM software installed in the CONFIG.SYS file. The program BIB.M, and the first three lines of GPCOM, are supplied by the card manufacturer and must be the correct revision for the particular version of the interface card in use. The interface card may be set up, using the program IBCONF.EXE, to set EOI with the last byte of Write in which case no terminator is required. (Read operations are automatically terminated on EOI which is always sent by the voltmeter). Normally, the options called 'high-speed timing', 'interrupt jumper setting', and 'DMA channel' should all be disabled.

The principles of using the Serial Poll Status Byte to control data transfer, as implemented in the main loop of GPCOM, are recommended for incorporation in the user's own programs.

```
10 'GPCOM 9-Feb-96
20 '....the following three lines and BIB.M are supplied by the.......
30 '....manufacturer of the GPIB card, must be correct version........
40 CLEAR , 60000!: IBINIT1 = 60000!: IBINIT2 = IBINIT1 + 3: BLOAD "BIB.M", IBINIT1
50 CALL IBINIT1(IBFIND, IBTRG, IBCLR, IBPCT, IBSIC, IBLOC, IBPPC, IBBNA, IBONL, IBRSC,
   IBSRE, IBRSV, IBPAD, IBSAD, IBIST, IBDMA, IBEOS, IBTMO, IBEOT, IBRDF, IBWRTF,
   IBTRAP)
60 CALL IBINIT2(IBGTS, IBCAC, IBWAIT, IBPOKE, IBWRT, IBWRTA, IBCMD, IBCMDA, IBRD,
   IBRDA, IBSTOP, IBRPP, IBRSP, IBDIAG, IBXTRC, IBRDI, IBWRTI, IBRDIA, IBWRTIA, IBSTA%,
   IBERR%, IBCNT%)
70 '................................................
80 CLS : PRINT "DEVICE MUST BE SET TO CR TERMINATOR"
90 '....assign access code to interface board.........
100 BDNAME$ = "GPIB0"
110 CALL IBFIND(BDNAME$, GPIB0%)
120 IF GPIB0% < 0 THEN PRINT "board assignment error": END
130 '....send INTERFACE CLEAR.........................
140 CALL IBSIC(GPIB0%)
150 '....set bus address, assign access code to device..........
160 SUCCESS% = 0
170 WHILE SUCCESS% = 0
180     INPUT "BUS ADDRESS "; A%
190     DEVNAME$ = "DEV" + RIGHT$(STR$(A%), LEN(STR$(A%)) - 1)
200     CALL IBFIND(DEVNAME$, DEV%)              ' assign access code
210     IF DEV% < 0 THEN PRINT "device assignment error": END
220     A$ = CHR$(13): GOSUB 480                 ' test: write <CR> to bus
230     IF IBSTA% > 0 THEN SUCCESS% = 1
240     IF (IBSTA% < 0 AND IBERR% = 2) THEN BEEP: PRINT "NO DEVICE AT THAT ADDRESS ";
250 WEND
260 '....send SELECTED DEVICE CLEAR...................
270 CALL IBCLR(DEV%)
280 '....set timeout to 1 second......................
```

```
290 V% = 11: CALL IBTMO(DEV%, V%)
300 '....set status print flag.....................
310 INPUT "Display status byte y/n "; R$
320 IF R$ = "Y" OR R$ = "y" THEN DS% = 1 ELSE DS% = 0
330 '....main loop................................
340 WHILE 1                                  ' infinite loop
350     INPUT "command (00 to exit) "; A$
360     IF A$ = "00" THEN END
370     A$ = A$ ' CHR$(13)                   ' terminator is <CR>
380     GOSUB 480                            ' write A$ to bus
390     S% = 0                               ' initialize S%
400     WHILE (S% AND 1) = 0                 ' while command not complete
410             GOSUB 530                    ' serial poll, returns S%
420             IF DS% THEN PRINT "S%= "; S%
430             IF (S% AND 128) THEN GOSUB 500: PRINT B$  ' read bus into B$ and print
440     WEND
445           IF (S% AND 4) THEN PRINT "parameter error"
450     IF (S% AND 2) THEN PRINT "invalid command"
460 WEND
470 '....end of main loop.........................
480 '....write string to bus.......................
490 CALL IBWRT(DEV%, A$): RETURN
500 '....read string from bus.....................
510 B$ = SPACE$(32)                          ' B$ is buffer
520 CALL IBRD(DEV%, B$): RETURN
530 '......serial poll............................
540 CALL IBRSP(DEV%, S%): RETURN
```

Cable Diagrams

Appendix D

D.1 RS232 Cable Diagrams

Users who choose to use the RS232 interface to connect the model 7310 Noise-Rejecting Voltmeter to a standard serial port on a computer will need to use one of two types of cable. The only difference between them is the number of pins used on the connector which goes to the computer. One has 9 pins and the other 25; both are null-modem (also called modem eliminator) cables in that some of the pins are cross-connected.

Users with reasonable practical skills can easily assemble the required cables from parts which are widely available through computer stores and electronics components suppliers. The required interconnections are given in figures D-1 and D-2.

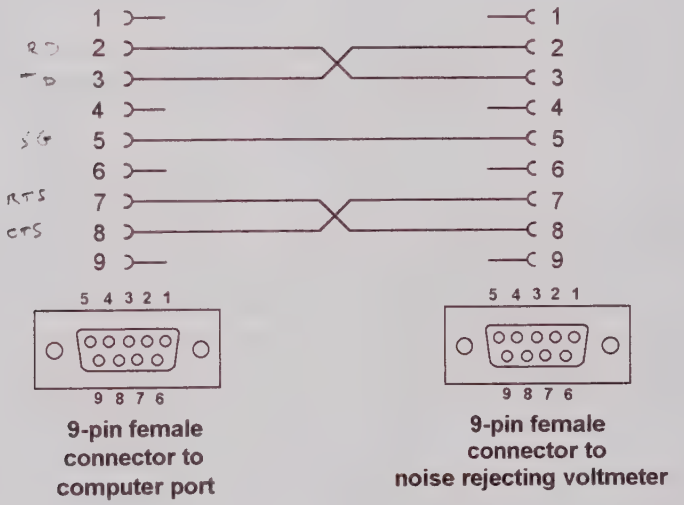


Figure D-1, Interconnecting RS232 Cable Wiring Diagram

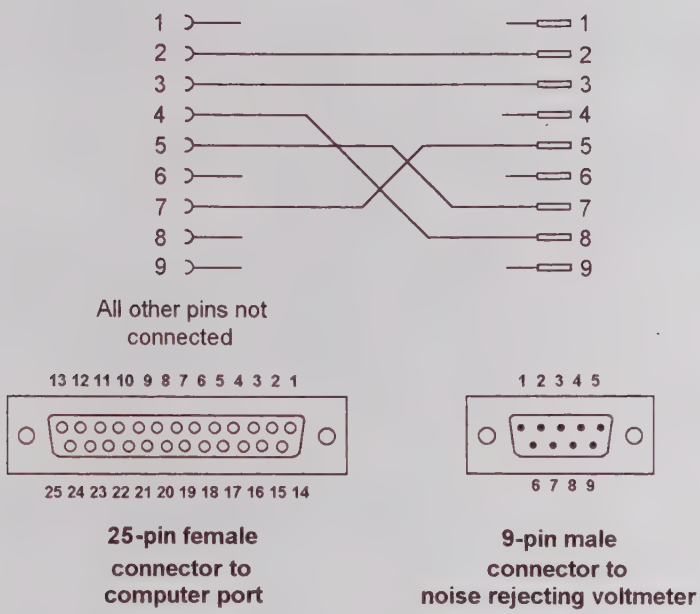


Figure D-2, Interconnecting RS232 Cable Wiring Diagram

Alphabetical Listing of Commands

Appendix E

* Transfer command

This command establishes the high-speed transfer mode. Use the STAR command to set up the desired response to the * command, and then send an * (ASCII 42), without terminator, to the instrument. The instrument will reply with the selected output as quickly as possible, and then wait for another *. If the computer processes the reply quickly and responds immediately with another *, then very rapid controlled data transfer is possible.

The first transfer takes a little longer than subsequent ones because some overhead time is required for the model 7310 to get into the high-speed transfer mode. When in this mode, the front panel controls are inactive and the display is frozen.

The mode is terminated either by sending any command other than an *, when the instrument will exit the mode and process the new command, or after a period of 10 seconds following the last * command.

NOTE: Check that the computer program does not automatically add a carriage return or carriage return-line feed terminator to the * command, since these characters will slow down communications.

\ n Address command

When the model 7310 is daisy-chained with other compatible instruments this command will change which instrument is addressed. All daisy-chained instruments receive commands but only the currently addressed instrument will implement or respond to the commands. The exception is the \ n command. If n matches the address set from the front panel the instrument will switch into addressed mode. If n does not match the address set from the front panel the instrument will switch into unaddressed mode. Note that the \ n command does not change the address of an instrument but which instrument is addressed.

NOTE: All instruments must have a unique address.

ACRMS [n] Voltmeter Measurement Mode Control

The ACRMS command sets the measurement mode of the instrument according to the following table:

n	Selection
0	DC measurement mode
1	AC RMS measurement mode

ADC n Read auxiliary analog to digital inputs

Reads the voltage appearing at the **ADC1** (n = 1) or **ADC2** (n = 2) inputs on the rear panel. The response for ADC1 and ADC2 is in volts.

ADF n Auto-Default command

This command will automatically set all the instrument controls and displays to the predefined states. The value of n is used to define which controls are affected, according to the following table:

n	effect
0	Complete reset to factory-set default values (listed in appendix F)
1	Reset to factory-set default values (listed in appendix F), with the exception of the RS232 and GPIB communications interface settings, and the LCD display contrast setting.

AOF Auto-Offset

The output offset is turned on and set to a level giving zero output. Any changes in the input signal then appear as changes about zero in the output.

AR Perform an Auto-Range operation

The instrument adjusts its full-scale sensitivity so that the output lies between 30 % and 90 % of full-scale.

AS Auto-Set 0dB

The AS command sets the present measured signal level to be the 0 dB level, which is used to calculate the dB output, and sets the Main Display to display this output type. Hence, for example, if the unit were displaying an output of 50 mV rms and the Auto-Set 0dB function were called, then the display would change to 0.000 dB. If the signal level then changed to 100 mV rms then this would appear as +6.02 dB in the dB display mode.

BURSTRATE [n] Sets the burst mode sampling rate for ADC1 and ADC2

The parameter n sets the sample rate for the Variable Rate burst modes according to the following equations:

When storing only to ADC1:
(i.e. TADC 2, TADC 4, TADC 6 and TADC 8)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 157} \right) \text{Hz}$$

When storing to ADC1 and ADC 2:
(i.e. TADC 3, TADC 5, TADC 7 and TADC 9)

$$\text{Sample Rate} = \left(\frac{16{,}000{,}000}{((25 \times n) + 1031} \right) \text{Hz}$$

For example when n = 20, the sample rate will be 24,353 Hz for ADC1.

BYTE [n] Digital output port control

The value of n, in the range 0 to 255, determines the bits to be output to the digital output port on the rear panel. When n = 0, all outputs are low, and when n = 255, all are high.

C n_1 [n_2] User equation constants

The C n_1 [n_2] command is used to specify the values of the two constants, C1 and C2, used in the user equation. Parameter n_1 is used to select the constant, with $n_1 = 1$ corresponding to constant C1 and $n_1 = 2$ corresponding to constant C2. Parameter n_2 sets the value of the selected constant and can lie in the range 0 to 99999.

CBD [n] Curve buffer define

Defines which data outputs are stored in the curve buffer when subsequent TD (take data), TDT (take data triggered) or TDC (take data continuously) commands are issued. Up to 8 curves, or outputs, may be acquired, as specified by the CBD parameter.

The CBD parameter is an integer between 0 and 2029, being the decimal equivalent of an 11-bit binary number. When a given bit is asserted, the corresponding output is selected for storage. When a bit is negated, the output is not stored. The bit function and range for each output are shown in the table below:

Bit	Decimal value	Output	Range
0	1	Output	see definition of OUT command
1	2	not used	
2	4	dB Output	see definition of OUTDB command
3	8	Ratio	
4	16	not used	
5	32	ADC1	±10.0 V
6	64	ADC2	±10.0 V
7	128	DAC1	±10.0 V
8	256	DAC2	±10.0 V
9	512	EVENT variable	0 to 32767
10	1024	User Equation	$\pm 2^{32}$

32768 points are available for data storage, shared equally between the specified curves. For example, if 8 outputs are stored then the maximum number of storage points would be 4096 (i.e. 32768/8). The LEN command sets the actual curve length, which cannot therefore be longer than 32768 divided by the number of curves selected. If more curves are requested than can be stored with the current buffer length, then the buffer length will be automatically reduced. Its actual length can of course be determined by sending the LEN command without a parameter.

DAC n_1 [n_2] Auxiliary DAC output controls

Sets the voltage appearing at the **DAC1, DAC2, DAC3** and **DAC4** outputs on the rear panel.

The first parameter n_1, which specifies the DAC, is compulsory and is either 1, 2, 3 or 4. The value of n_2 specifies the output voltage in volts, in the range -12.000 V to +12.000 V.

DCT n Dump acquired curves to computer in table format

The DCT command is used to transfer data stored in the curve buffer to the controlling computer. The DCT parameter is an integer between 1 and 2029, being the decimal equivalent of an 11-bit binary number. When a given bit in the number is asserted, the corresponding curve is selected for transfer. When a bit is negated, the curve is not transferred. The bit corresponding to each curve is shown in the table below:

Bit	Decimal value	Curve	Range
0	1	Output	see definition of OUT command
1	2	not used	
2	4	dB Output	see definition of OUTDB command
3	8	Ratio	
4	16	not used	
5	32	ADC1	±10.0 V
6	64	ADC2	±10.0 V
7	128	DAC1	±10.0 V
8	256	DAC2	±10.0 V
9	512	EVENT variable	0 to 32767
10	1024	User Equation	$\pm 2^{32}$

The values of the selected curves at the same sample point are transferred as a group in the order of the above table, separated by the chosen delimiter character and terminated with the selected terminator. This continues until all the points have been transferred.

As an example, suppose CBD 33 had been sent, equivalent to asserting bits 0 and 5, then the Output and ADC1 values would be stored. The permitted values of n would therefore be 1, 32 and 33. DCT 1 and DCT 32 would transfer only one curve at a time, but DCT 33 would transfer the Output curve and the ADC1 curve simultaneously. A typical output data sequence would be:

<Output value$_1$><delim><ADC1 value$_1$><term>
<Output value$_2$><delim><ADC1 Value$_2$><term>
<Output value$_3$><delim><ADC1 Value$_3$><term>
<Output value$_4$><delim><ADC1 Value$_4$><term>
<Output value$_5$><delim><ADC1 Value$_5$><term>

etc., where <delim> and <term> are the delimiter and terminator characters respectively.

The computer program's subroutine which reads the responses to the DCT command needs to run a FOR...NEXT loop of length equal to the value set by the LEN (curve length) command, and must be able to separate the responses on each line for storage or processing.

Note that when using this command with the GPIB interface the serial poll must be used. After sending the DCT command, perform repeated serial polls until bit 7 is set, indicating that the instrument has an output waiting to be read. Then perform repeated reads in a loop, waiting each time until bit 7 is set, indicating that a new

value is available. The loop should continue until bit 1 is set, indicating that the transfer is completed.

DCOUT [n] Analog output control

Defines which output appears at the **DC OUTPUT** connector on the rear panel, according to the following table:

n	Signal
0	Output
1	dB Output
2	Ratio
3	Log Ratio
4	Equation

The relationship between the analog signal appearing at the connector and the front-panel display value, for each of the five possible settings, is given in section 5.3.06.

DD [n] Define delimiter control

The value of n, which can be set to 13 or from 32 to 125, determines the ASCII value of the character sent by the instrument to separate two numeric values in a two-value response, such as that generated by the DCT command.

DEFEQU [n_1 n_2 n_3 n_4 n_5] Define user equation

The DEFEQU command is used to define the user equation, which takes the following form:

$$\text{Equation} = \left(\frac{(A \pm B) \times C}{D} \right)$$

The parameter n_2 is used to set the addition/subtraction operator in the numerator according to the following table:-

n_2	Operator
0	Subtraction
1	Addition

The parameters n_1, n_3, n_4 and n_5 specify the variables A, B, C and D respectively according to the following table:

n	Variable	Range
0	OUT	±30000
1	ADC1	±10000
2	ADC2	±10000
3	C1	0 to 99999
4	C2	0 to 99999
5	0	zero
6	1	unity

DISP n Display Mode Control

The DISP n command is used to set the display to two of the three possible display modes, as follows:

n	Display
0	Main Display
1	Large Digits Display

DISPOUT n_1 [n_2] Main Display Output Selector

This command is used to specify which outputs are displayed on the Main Display. Parameter n_1 specifies the display to be modified and is either 0 or 1, corresponding to the top and bottom positions on the right-hand side of the display. Parameter n_2 is used to choose which output appears in the chosen position, in accordance with the following table:-

Top Display Position (n_1 = 0), always a digital meter.
Note that this also sets the output which appears in the Large Digits display.

n_2	Displayed Output
0	ADC1
1	ADC2
2	Output
3	dB Output

Bottom Display Position (n_1 = 1)

n_2	Displayed Output and Type
0	ADC1, center zero bar-graph
1	ADC2, center zero bar-graph
2	Output, bar-graph
3	ADC1, small digital display
4	ADC2, small digital display
5	Output, small digital display

EQU Output result of user-specified equation

The value returned is the output of the user equation, where the equations are defined using the Equation Setup menus (see section 5.3.07) or via the DEFEQU command. The possible range is ±2,147,483,647 (signed 32-bit integer).

EVENT [n] Event marker control

During a curve acquisition, if bit 9 in the CBD command has been asserted, the instrument stores the value of the Event variable at each sample point. This can be used as a marker to indicate the point at which an experimental parameter was changed. The EVENT command is used to set this variable to any value between 0 and 32767.

FILT [n] Filter Mode Control

The FILT command sets the measurement mode of the digital filter according to the following table:

n	Filter Mode
0	Flat
1	Low-pass
2	Bandpass

FILTF [n] Filter Frequency Control

The FILTF [n] command sets the digital filter frequency according to the following paragraphs:

No filter mode (i.e. FILT 0)

The command has no effect, since the digital filter is inactive

Low-pass filter mode (i.e. FILT 1)

The parameter n sets the -3 dB cut-off frequency in hertz to any value between 10 Hz and 60 kHz, with a 1 Hz resolution.

Bandpass filter mode (i.e. FILT 2)

The parameter n sets the center frequency in hertz to any value between 1 Hz and 60 kHz, with a 1 Hz resolution.

FILTQ [n] Bandpass Filter *Q*-Factor Control

The FILTQ [n] command sets the digital bandpass filter *Q*-factor to values between 2 and 100, according to the following table:

n	*Q*-factor
0	2
1	5
2	10
3	20
4	50
5	100

FLOAT [n] Input connector shield float/ground control

The value of n sets the input connector shield switch according to the following table:

n	Selection
0	Ground
1	Float (connected to ground via a 1 kΩ resistor)

GP [n_1 [n_2]] Set/Read GPIB parameters

n_1 sets the GPIB address in the range 0 to 31

n_2 sets the GPIB terminator and the test echo function according to the following table:

n	Terminator
0	[CR], test echo disabled
1	[CR], test echo enabled
2	[CR,LF], test echo disabled
3	[CR,LF], test echo enabled
4	no terminator, test echo disabled
5	no terminator, test echo enabled

In all cases the EOI line is asserted with the last byte of a response.

When the test echo is on, every character transmitted or received via the GPIB port is echoed to the RS232 port. This is provided solely as an aid to program development and should not be enabled during normal operation of the instrument.

HC Halt curve acquisition

Halts curve acquisition in progress. It is effective during both single (data acquisition initiated by TD or TDT command) and continuous (data acquisition initiated by TDC command) curve acquisitions. The curve may be restarted by means of the TD, TDT or TDC command, as appropriate.

ID Identification

Causes the instrument to respond with the number 7310.

IMODE [n] Current/Voltage mode input selector

The value of n sets the input mode according to the following table:

n	Input mode
0	Current mode off - voltage mode input enabled
1	Current mode enabled - connect signal to **B** input connector

If n = 0 then the input configuration is determined by the VMODE command.
If n = 1 then current mode is enabled irrespective of the VMODE setting.

LEN [n] Curve length control

The value of n sets the curve buffer length in effect for data acquisition. The maximum allowed value depends on the number of curves requested using the CBD command, and a parameter error results if the value given is too large. For this reason, if the number of points is to be increased and the number of curves to be stored is to be reduced using the CBD command, then the CBD command should be issued first.

LF [n_1 n_2] Signal channel line frequency rejection filter control

The LF command sets the mode and frequency of the line frequency rejection (notch) filter according to the following tables:

n_1	Selection
0	Off
1	Enable 50 or 60 Hz notch filter
2	Enable 100 or 120 Hz notch filter
3	Enable both filters

n_2	Notch Filter Frequency
0	60 Hz (and/or 120 Hz)
1	50 Hz (and/or 100 Hz)

LR Log Ratio output

The LR command reports a number equivalent to log(OUTPUT/ADC1), where OUTPUT is the value that would be returned by the OUT command and ADC1 is the value that would be returned by the ADC1 command. The response range is -3.000 to +2.079

LTS [n] Lights on/off control

The value of n controls the front panel LEDs and LCD backlight according to the following table:

n	Selection
0	All lights off
1	Normal operation

M Curve acquisition status monitor

Causes the instrument to respond with four values that provide information concerning data acquisition, as follows:

First value, Curve Acquisition Status: a number with five possible values, defined by the following table:

First Value	Significance
0	No curve activity in progress.
1	Acquisition via TD or TDT command in progress and running.
2	Acquisition via TDC command in progress and running.
5	Acquisition via TD or TDT command in progress but halted by HC command.
6	Acquisition via TDC command in progress but halted by HC command.

Second value, Number of Sweeps Acquired: This number is incremented each time a TD or TDT is completed and each time a full cycle is completed on a TDC acquisition. It is zeroed by the NC command and also whenever a CBD or LEN command is applied without parameters.

Third value, Status Byte: The same as the response to the ST command. The number returned is the decimal equivalent of the status byte and refers to the previously applied command.

Fourth value, Number of Points Acquired: This number is incremented each time a point is taken. It is zeroed by the NC command and whenever CBD or LEN is applied without parameters.

MAX Read Maximum Output

The MAX command returns the maximum output value, since the last reset operation. The response is in volts or amps, depending on whether voltage or current input mode is selected, as follows:

Voltage Input Mode
The response lies in the range +0.0E00 (0 V) and +2.0E00 (2 V) (AC mode) or -2.0E00 (-2 V) and +2.0E00 (2 V) (DC mode)

Current Input Mode
The response lies in the range +0.0E00 (0 A) and +2.0E-06 (2 µA) (AC mode) or -2.0E-06 (-2 µA) and +2.0E-06 (2 µA) (DC mode)

MIN Read Minimum Output

The MIN command returns the minimum output value, since the last reset operation. The response is in volts or amps, depending on whether voltage or current input mode is selected, as follows:

Voltage Input Mode
The response lies in the range +0.0E00 (0 V) and +2.0E00 (2 V) (AC mode) or -2.0E00 (-2 V) and +2.0E00 (2 V) (DC mode)

Current Input Mode
The response lies in the range +0.0E00 (0 A) and +2.0E-06 (2 µA) (AC mode) or -2.0E-06 (-2 µA) and +2.0E-06 (2 µA) (DC mode)

MSK [n] Set/read service request mask byte

The value of n sets the SRQ mask byte in the range 0 to 255

NC New curve

Initializes the curve storage memory and status variables. All record of previously taken curves is removed.

OF [n_1 [n_2]] Offset control

The value of n_1 sets the status of the offset facility according to the following table:

n_1	Selection
0	Disables offset
1	Enables offset facility

The range of n_2 depends on the measurement mode of the instrument, as follows:

DC measurement Mode

n_2 may be set to any value between 0 and ±100 %, in 0.01 % increments, of the present full-scale sensitivity range setting, and is specified in volts or amps, depending on the present input mode. For example, if the range is set to 500 mV, n_2 can range from -500E-3 to +500E-3 in steps of 5E-5.

AC measurement Mode

In voltage mode, n_2 may be set to any value between 0 and -1 V, in 1 nV increments, whilst in current mode, n_2 may be set to any value between 0 and -1 μA in 1 fA increments. In addition, the magnitude of the specified offset level must be less than the measured signal level with offset disabled.

OUT Output

The OUT command causes the instrument to respond with the output in volts or amps, depending on whether voltage or current input mode is selected, as follows.

Voltage Input Mode

The response lies in the range +0.0E00 (0 V) and +2.0E00 (2 V) (AC mode) or -2.0E00 (-2 V) and +2.0E00 (2 V) (DC mode)

Current Input Mode

The response lies in the range +0.0E00 (0 A) and +2.0E-06 (2 μA) (AC mode) or -2.0E-06 (-2 μA) and +2.0E-06 (2 μA) (DC mode)

OUTDB dB Output

The OUTDB command causes the instrument to respond with the output expressed in decibels with respect to the preset zero dB level, as defined by the ZERODB command or set by the Auto-set 0dB function. The response range is +12.0E1 (120 dB) to -6.0E1 (-60 dB).

RANGE [n]
RANGE. Full-scale sensitivity control

The value of n sets the full-scale sensitivity according to the following table, depending on the setting of the IMODE control:

n	full-scale sensitivity	
	IMODE=0	IMODE=1
0	10 μV	10 pA
1	20 μV	20 pA
2	50 μV	50 pA
3	100 μV	100 pA
4	200 μV	200 pA
5	500 μV	500 pA
6	1 mV	1 nA
7	2 mV	2 nA
8	5 mV	5 nA
9	10 mV	10 nA
10	20 mV	20 nA
11	50 mV	50 nA
12	100 mV	100 nA

n	full-scale sensitivity	
	IMODE=0	IMODE=1
13	200 mV	200 nA
14	500 mV	500 nA
15	1 V	1 μA

The RANGE [n] command can be used to set and read the sensitivity, whilst the RANGE. command can only be used for reading it. The response to the RANGE. command is in volts or amps. For example, if IMODE = 0 and the sensitivity is 1 mV the command RANGE would report 6 and the command RANGE. would report +1.0E-03. If IMODE was changed to 1, RANGE would still report 6 but RANGE. would report +1.0E-09.

REMOTE [n] Remote only (front panel lock-out) control

Allowed values of n are 0 and 1. When n is equal to 1, the instrument enters remote only mode in which the front panel control functions are inoperative and the instrument can only be controlled with the RS232 or the GPIB interfaces. When n is equal to 0, the front panel controls function normally.

RESET Reset Maximum and Minimum Indicators

The RESET command duplicates the function provided by the **RESET** key on the front panel and the **RESET MAX/MIN** input on the rear panel, and resets the Maximum and Minimum output level indicators.

REV Report firmware revision

Causes the instrument to respond with the firmware revision number. This gives a four line response which the controlling program must be able to accept.

RS [n_1 [n_2]] Set/read RS232 interface parameters

The value of n_1 sets the baud rate of the RS232 interface according to the following table:

n_1	Baud rate (bits per second)
0	75
1	110
2	134.5
3	150
4	300
5	600
6	1200
7	1800
8	2000
9	2400
10	4800
11	9600
12	19200

The lowest five bits in n_2 control the other RS232 parameters according to the following table:

STR [n] Storage interval control

Sets the time interval between successive points being acquired under the TD or TDC commands. n specifies the time interval in seconds with a resolution of 5 ms, input values being rounded up to a multiple of 5 ms. The longest interval that can be specified is 100,000 s corresponding to one point in about 27¾ hours.

In addition, n may be set to 0, which sets the time per point to 1.25 ms. However this only allows storage of the output. There is no need to issue a CBD 1 command to set this up since it happens automatically when acquisition starts.

TADC [n] Auxiliary ADC trigger mode control

The value of n sets the trigger mode of the auxiliary **ADC** inputs according to the following table:

n	Trigger mode
0	Asynchronous (5 ms intervals)
1	External (rear panel **TRIGGER** input)
2	Burst mode, fixed rate, triggered by command (ADC1 only)
3	Burst mode, fixed rate, triggered by command (ADC1 and ADC2)
4	Burst mode, variable rate, triggered by command (ADC1 only)
5	Burst mode, variable rate, triggered by command (ADC1 and ADC2)
6	Burst mode, fixed rate, External trigger (rear panel **TRIGGER** input) (ADC1 only)
7	Burst mode, fixed rate, External trigger (rear panel **TRIGGER** input) (ADC1 and ADC2)
8	Burst mode, variable rate, External trigger (rear panel **TRIGGER** input) (ADC1 only)
9	Burst mode, variable rate, External trigger (rear panel **TRIGGER** input) (ADC1 and ADC2)

In the burst modes, data is stored in the curve buffer. Use the LEN command to set the number of points required. Note that it may be necessary to enter CBD 32 before setting the length, if the curve buffer has previously been used for more than one data type. The data is read out from the buffer using DCT 5 for ADC1 and DCT 6 for ADC2. If the length is set to more than 16384 and a burst mode which stores both ADC1 and ADC2 is specified then the curve length will automatically be reduced to 16384 points. Note also that setting the TADC parameter to any value other than 0 or 1 may affect the CBD parameter, as follows:

TADC parameter	Effect on CBD parameter
0	none
1	none
2	automatically set to 32
3	automatically set to 96
4	automatically set to 32
5	automatically set to 96
6	automatically set to 32
7	automatically set to 96
8	automatically set to 32
9	automatically set to 96

bit number	bit negated	bit asserted
0	data + parity = 8 bits	data + parity = 9 bits
1	no parity bit	1 parity bit
2	even parity	odd parity
3	echo disabled	echo enabled
4	prompt disabled	prompt enabled

RT Ratio output

The RT command reports a number equivalent to OUTPUT/ADC1 where OUTPUT is the value that would be returned by the OUT command and ADC1 is the value that would be returned by the ADC1 command.

SLOPE [n] Output smoothing slope (roll-off) control

The value of n sets the slope of the output filters according to the following table:

n	Slope
0	6 dB/octave
1	12 dB/octave

ST Report status byte

Causes the instrument to respond with the status byte, an integer between 0 and 255, which is the decimal equivalent of a binary number with the following bit-significance:

Bit 0	Command complete
Bit 1	Invalid command
Bit 2	Command parameter error
Bit 3	Rear-panel DC OUTPUT overload
Bit 4	Signal Channel/DSP Output overload
Bit 5	New ADC values available after external trigger
Bit 6	Asserted SRQ
Bit 7	Data available

NOTE: this command is not normally used in GPIB communications, where the status byte is accessed by performing a serial poll.

STAR [n] Star mode setup command

The star mode allows faster access to instrument outputs than is possible using the conventional commands. The mode is set up using the STAR command to specify the output(s) required and invoked by sending an asterisk (ASCII 42) to request the data. The data returned is specified by the value of n, as follows:

n	Data returned by * command
0	OUT
1	ADC1
2	ADC2
3	OUT & ADC1
4	ADC1 & ADC2

The maximum sampling rate depends on the number of ADC inputs used and whether the sampling is timed or simply runs as fast as possible. In the modes above described as Fixed Rate, sampling runs at the maximum possible rate, nominally 20 kHz, when sampling both ADC1 and ADC2 or 40 kHz when sampling ADC1 only. In the Variable Rate modes, the sampling speed is set by the BURSTRATE command.

TC [n]
TC. Output smoothing time constant control

The value of n sets the output smoothing output time constant according to the following table:

n	output smoothing time constant
0	5 ms
1	10 ms
2	20 ms
3	50 ms
4	100 ms
5	200 ms
6	500 ms
7	1 s
8	2 s
9	5 s
10	10 s

The TC. command is only used for reading the output smoothing time constant, and reports the current setting in seconds. Hence if a TC 5 command were sent, TC would report 5 and TC. would report 2.0E-01, i.e. 0.2 s or 200 ms.

TD Take data

Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until the buffer is full.

TDC Take data continuously

Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until halted by an HC command. The buffer is circular in the sense that when it has been filled, new data overwrites earlier points.

TDT n Take data triggered

Sets the instrument so that data acquisition will be initiated on receipt of a trigger at the **TRIGGER** connector on the rear panel. Two triggered modes are possible, as set by the value of n:

n	function
0	One complete curve is acquired for each trigger
1	One complete set of data points is acquired for each trigger. Note that in this mode the maximum trigger rate is 200 Hz and the storage interval control setting has no effect.

VER Report firmware version

Causes the instrument to respond with the firmware version number. The firmware version number is the number displayed on the front panel LCD Settings menu.

VMODE [n] Voltage input configuration

The value of n sets up the input configuration according to the following table:

n	Input configuration
0	Both inputs grounded (test mode)
1	A input only
2	B input only
3	A-B differential mode

Note that the IMODE command takes precedence over the VMODE command.

ZERODB [n] Set 0dB Level

The ZERODB command sets the 0 dB level used for calculation when the output mode is set to dB. The parameter n sets the level directly in volts or amps, depending on whether voltage or current input mode is selected, as follows:

Voltage Input Mode

The parameter n can be set to any value between 1E-9 (1 nV) and 1 (1 V)

Current Input Mode

The parameter n can be set to any value between 1E-15 (1 fA) and 1E-6 (1 μA)

Default Settings

Appendix F

Auto Default Function

The Auto-Default computer command ADF 1 sets the model 7310's controls and output displays as follows:-

Operating Mode
Volts AC RMS

Digital Filter
Sets the instrument to bandpass filter mode, with a center frequency of 1000 Hz and a *Q*-factor of 2, giving a -3 dB bandwidth of 321.7 Hz. The operating sensitivity range is 500 mV full-scale.

Main Display
The large digital meter on the upper right-hand side and the bar-graph on the lower right-hand side of the display shows the measured signal in volts rms. The maximum and minimum signal level indicators are reset.

The remaining instrument controls, accessed via the menus, are set as follows:-

Signal Channel	
Operating Mode	AC
Input mode	Single-ended voltage mode, **A** input connector
Input connector shell	Floating
Line frequency rejection filter	Off
Output Channel	
Output offset level	0.000 V
Output offset status	Off
DC Output	Output
Output Smoothing Time Constant	100 ms
Output Smoothing Slope	12 dB/octave
Equation Setup	
Equation	zero
DACs	
DAC1 output	0.000 V
DAC2 output	0.000 V
DAC3 output	0.000 V
DAC4 output	0.000 V

ADCs

ADC1 & 2 Trigger Rate	5 ms

Curve Buffer

Time per point	10 ms
Length	32768

Curve Select

Selected curve	OUTPUT

'*' Command Options

Selected output	OUT

Digital Port

Digital outputs	0 (i.e. D0 - D7 are at logic zero)

LCD Settings

Contrast	Not changed
Backlight	On

The Auto-Default function on the front-panel Auto Functions menu and the ADF 0 computer command set the model 7310's controls and output displays as above, and in addition set the communications interface parameters and the LCD Settings menu display contrast item as follows:-

RS232 Comms

Baud rate	9600
Data bits	7 + 1 Parity
Delimiter	, (a comma, ASCII code 044)
Address	1
Character echo	On
Parity	Even
Prompt character	On

GPIB Comms

Address	11
Terminator	[CR],[LF]
Test Echo	Disabled
SRQ mask byte	0

LCD Settings

Display contrast	65

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B. We will need the following information, a copy of which should also be attached to any equipment which is returned for service.

1. Model number and serial number of instrument
2. Your name (instrument user)
3. Your address
4. Address to which the instrument should be returned
5. Your telephone number and extension
6. Symptoms (in detail, including control settings)
7. Your purchase order number for repair charges (does not apply to repairs in warranty)
8. Shipping instructions (if you wish to authorize shipment by any method other than normal surface transportation)

C. If you experience any difficulties in obtaining service please contact

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